Effectiveness of Interactive Video Lessons in Improving Twelfth-Grade Students' Understanding of Electric Field Concepts

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ABSTRACT

This convergent mixed-methods study, implemented within a practitioner action-research cycle, examined whether interactive video lessons (IVLs) supported Bhutanese twelfth-grade students' conceptual understanding of electric fields. The quantitative strand used a non-equivalent-groups quasi-experimental design with two intact science sections ($N = 68$; 34 students per group), and the qualitative strand used phenomenological interviews with six students from the experimental group. Individual students were not randomly assigned. The experimental group learned through Edpuzzle-based IVLs, whereas the control group received lecture-based instruction. Achievement-test scores were analyzed using Mann-Whitney U tests for between-group comparisons and Wilcoxon signed-rank tests for within-group pre-post change; survey responses were summarized descriptively, and interviews were analyzed thematically. No statistically significant pre-test difference was detected ($U = 542$, $p = .436$, $r_{rb} = .062$). At post-test, the median was 14 for the experimental group and 8 for the control group ($U = 304$, $p < .001$, $r_{rb} = .474$). Students generally described the IVLs as engaging and useful, although pacing, accent clarity, audio quality, and the need for teacher scaffolding were identified as challenges. Because the study used intact classes and the archived analytical output did not contain a direct between-group change-score analysis or confidence intervals for the reported rank-biserial correlations, the findings are interpreted as preliminary, association-based evidence rather than definitive causal evidence of IVL effectiveness.

Keywords: interactive video lessons; electric fields; Edpuzzle; conceptual understanding; quasi-experimental design; mixed methods; action research

INTRODUCTION

The abstract nature of electric field concepts in physics presents a significant challenge for students. Garza and Zavala (2013) report that even advanced learners struggle to accurately represent electric fields and forces. Traditional "chalk and talk" methods often fail to help students visualize such concepts, while factors such as limited teacher expertise, outdated textbooks, and scarce reference materials further hinder learning (Mohammed & Adigun, 2020). Similar patterns are evident among twelfth-grade physics students, who often experience misconceptions and lack the confidence to apply these principles.

Digital tools, such as animations and simulations, can support comprehension; however, passive viewing alone may not foster deep conceptual understanding or sustained engagement. Interactive video lessons (IVL) address this gap by embedding questions, simulations, and problem-solving tasks directly into videos. This participatory approach has the potential to strengthen the conceptual grasp and retention of electric field principles.

This practitioner-led investigation primarily used a convergent mixed-methods design. Its quantitative component was a non-equivalent-groups quasi-experiment, while its qualitative component explored students' lived experiences of IVL-based learning. Action research provided the classroom-improvement framework through which the intervention was planned, implemented, observed, and reflected upon.

Aims of the Study

This study aims to evaluate the effectiveness of IVLs in improving students' understanding of electric field concepts and to explore students' perceptions and challenges related to IVL use.

Objectives

i. To determine whether IVL-supported instruction is associated with improved conceptual understanding of electric field concepts compared with lecture-based instruction.

ii. To examine students' perceptions of learning electric field concepts through IVLs.

iii. To identify the challenges students experience when learning electric field concepts through IVLs.

Significance of the Study

This research offers valuable insights for physics teachers in designing strategies that leverage interactive videos to make abstract topics more accessible to students. For students, IVL provides a platform to visualize and better understand challenging concepts, fostering engagement and comprehension.

Traditional assessment methods, such as quizzes and written assignments, are time-consuming and provide delayed feedback. Using Edpuzzle's interactive timeline, teachers can automatically track engagement metrics, including pauses, replays, and skipped sections of the video. This real-time feedback highlights areas of difficulty, enabling immediate intervention before misconceptions are established. Such automated, continuous assessment makes formative evaluation more efficient and responsive to students' needs.

At the policy level, findings shared with the Ministry of Education (MoE) could inform professional development programs, workshops, and training on IVL integration, ultimately making teaching and learning more engaging and effective for students.

LITERATURE REVIEW

Multimedia in Education and Interactive Video Lessons

Multimedia in education integrates various formats, such as text, audio, and video, to create enriched learning experiences (Sadaghiani, 2010). Richtberg and Girwidz (2019) emphasize that for videos to be effective learning tools, they must be interactive rather than passive, fostering active information processing and deeper comprehension. Although traditional videos serve well to deliver content (Dieck-Assad et al., 2020), their effectiveness largely depends on incorporating activities tailored to meet learners' specific needs. Advances in educational technology now enable videos to embed interactive elements, such as quizzes, hotspots, and three-dimensional objects, thereby enhancing student engagement (Gedera & Zalipour, 2018). Platforms such as Edpuzzle, PlayPosit, and Camtasia facilitate the creation of such interactive videos (Baker, 2016), with this study specifically utilizing Edpuzzle.

Benefits of Interactive Video Lessons

Research has demonstrated the multiple benefits of interactive videos in education. For instance, Ipek et al. (2020) found that Turkish teacher candidates preferred question-enriched interactive videos within blended learning environments, whereas Malaysian students showed increased participation when interactivity was creatively designed (Ti-Shen & Sen, 2019). These findings suggest that interactive videos can motivate learners and sustain their attention more effectively than passive viewing. Additionally, Keller et al. (2019) observed that interactive videos outperform hypertext in acquiring procedural knowledge and significantly improving learning quality. Similarly, students who watched interactive videos performed significantly better than those who watched non-interactive videos, did not watch videos, or performed typical classroom activities, and reported greater learning pleasure (Zhang et al., 2004). In applied electronics courses, Dieck-

Assad et al. (2020) reported that students benefited from enhanced motivation and deeper conceptual mastery when using interactive video lessons that allowed for repeated content review. Furthermore, Althwaini and Mahmoud (2021) showed that adding visual cues to interactive videos significantly improved student achievement.

The flexibility afforded by interactive videos also contributes to their effectiveness. Gedera and Zalipour (2018) noted that educators and students in New Zealand appreciated interactive videos for enabling self-paced learning and improving their cognitive efficiency. Considering this finding, Smithwick et al. (2017) also found that when watching interactive videos, students reported gains in learning and an improvement in their ability to learn at their own pace.

According to Pulukuri and Abrams (2020), students found IVL to be engaging, effective, and helpful in learning. Complementary studies by Zhang et al. (2006) and Schwan and Riempp (2004) support these findings, highlighting gains in student performance and satisfaction. Together, these studies affirm the multifaceted advantages of interactive videos in fostering student engagement, motivation, and learning efficiency in higher education.

Challenges in Implementing Interactive Videos

Despite these strengths, challenges persist in the use of interactive video. Karppinen (2005) and Yeo et al. (2004) emphasize that the mere presentation of video content is insufficient; effective interactive videos require thoughtfully embedded prompts and questions to maintain learner engagement and promote active learning. Additionally, Debowska et al. (2013) and Gedera and Zalipour (2018) highlight the difficulties educators face in sourcing or creating relevant multimedia resources, underscoring the importance of professional development and workshops to equip teachers with the necessary skills for designing interactive lessons effectively. Moreover, although several studies have addressed the use of interactive videos broadly, there is a notable lack of empirical research focused specifically on teaching electric field concepts in physics through interactive video lessons. Given the abstract and challenging nature of this topic, this gap signifies an important area of investigation.

Research Questions

1. To what extent do students taught through IVLs differ from students taught through lecture-based instruction in their pre-post achievement in electric field concepts? 2. How do students perceive IVL-supported learning? 3. What challenges do students experience during IVL-supported learning?

METHODOLOGY

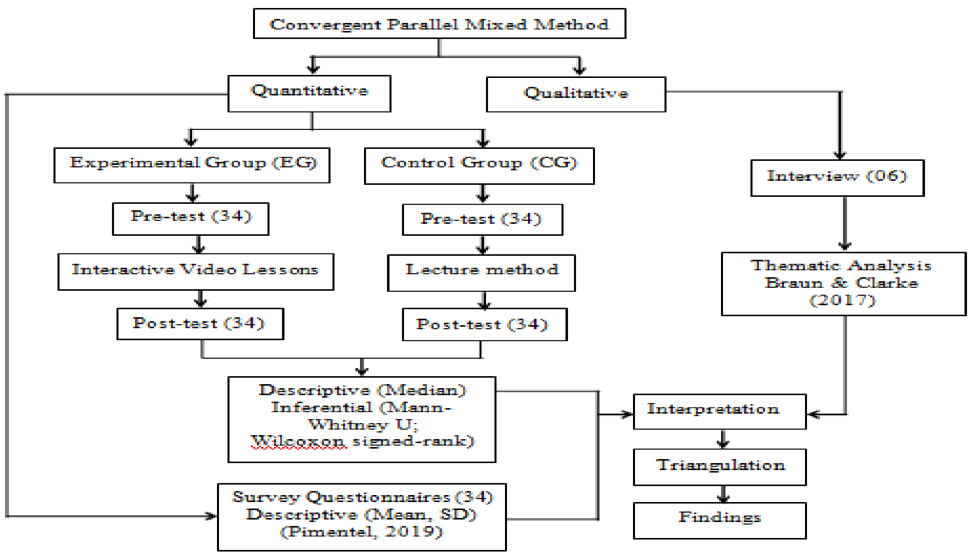


Figure 3.1

RESEARCH METHODOLOGY

Research Approach and Design

The primary design was convergent mixed methods: the quantitative and qualitative strands were implemented during the same study period, analyzed separately, and integrated during interpretation (Creswell & Plano Clark, 2018). The quantitative strand used a quasi-experimental, pre-test-post-test design with non-equivalent intact groups. The qualitative strand used a descriptive phenomenological approach to examine how students experienced IVL-supported learning (Sundler et al., 2019). The term action research refers to the practitioner-led improvement cycle surrounding the study, rather than to a separate causal design. The researchers identified a classroom learning problem, planned and implemented IVLs, observed outcomes through achievement tests, surveys, platform information, and interviews, and reflected on improvements for subsequent teaching.

Two existing Grade XII science sections were retained to avoid disrupting the school timetable. Allocation occurred at the class-section level, not at the individual-student level; consequently, the groups were treated as non-equivalent. Baseline comparability was examined using pre-test distributions and a Mann-Whitney U test. Both groups had a pre-test median of 0, and no statistically significant difference was detected ($U = 542$, $p = .436$, $r_{rb} = -.062$). This result indicates that the analysis did not detect a baseline difference, but it does not establish statistical equivalence or eliminate selection bias. The qualitative and quantitative findings were compared at the interpretation stage to identify convergence, complementarity, and divergence.

Participants Group Assignment and Baseline Comparability

The school was selected through convenience sampling, and two intact Grade XII science sections were included. The existing class sections were retained to preserve the normal school timetable, and allocation was therefore made at the class-section level rather than through individual student randomization. One intact section constituted the experimental group and the other the control group; accordingly, the groups were treated as non-equivalent. The final achievement-test analysis comprised 68 students, with 34 students in each condition. Participant reporting in this manuscript is based consistently on this final analytic sample. The available study file does not contain a sufficiently detailed stage-by-stage attrition record to reconstruct earlier provisional enrolment counts or assign reasons for any discrepancy without speculation. All 34 students in the experimental group were invited to complete the perception survey, and six students, comprising three male and three female participants, were purposively selected for interviews.

Intervention and Comparison Conditions

The experimental condition used IVLs delivered through Edpuzzle during the regular instructional unit on electric-field concepts. The documented content included electric-field representation, Coulomb's law, inverse-square relationships, and the superposition of electric fields. The videos combined narration and visual representations with embedded conceptual questions and problem-solving prompts. Students could pause and replay segments, submit responses at embedded checkpoints, and review feedback, thereby supporting self-paced engagement with difficult concepts. The intervention was implemented within scheduled physics lessons. The archived study documentation records the intervention content and learning sequence but does not retain sufficiently detailed session-level logs to report exact intervention dates, the total number and duration of lessons, or the number and average duration of videos without retrospective reconstruction; these details are therefore not estimated.

The intended learning sequence required students to predict or interpret electric-field behavior, respond to embedded questions, use visualizations or simulations to examine relationships, and solve application problems before class discussion. Edpuzzle information on viewing, pauses, replays, skipped segments, and submitted responses was used formatively to identify areas in which students required additional clarification. The study record confirms the use of visual representations and simulation-based explanations but does not preserve the names of specific external simulation packages, the exact number of embedded questions by type, or a separate implementation-fidelity log. These instructional features are therefore reported at the functional level supported by the available documentation rather than attributed to unverified resources or counts.

The comparison group received lecture-based instruction on the corresponding curriculum content. In the experimental condition, the teacher introduced the intended learning outcomes, monitored students' engagement with the IVLs and their responses to embedded questions, provided scaffolding when conceptual difficulties were identified, and facilitated post-video discussion and debriefing to consolidate learning. Both conditions addressed the same prescribed electric-field topics and learning objectives. The available study record does not provide sufficiently detailed information to establish strict equivalence in total instructional minutes, supplementary learning resources, assessment opportunities, or teacher assignment across conditions; consequently, comparability is claimed at the level of curricular content and learning objectives rather than as complete instructional equivalence.

Data Collection Instruments

Physics Achievement Test. The same achievement-test framework was administered before and after instruction to measure students' conceptual understanding and change over time. The content domain covered electric-field representation, Coulomb's law, inverse-square reasoning, and the superposition of electric fields. The assessment framework emphasized interpretation of representations, application of physical relationships, explanation of reasoning, and problem solving rather than simple factual recall. Items were scored using a common marking scheme, and total scores were used in the group analyses. The archived manuscript file does not retain the complete item-by-item test blueprint, the number and format of individual items, the maximum score and administration-time record, or documentation establishing whether the pre-test and post-test were identical or parallel forms. These characteristics are therefore not retrospectively reconstructed or reported as verified facts.

Perception survey. The experimental group completed a 22-item questionnaire in Google Classroom after the intervention. Items assessed perceived effectiveness, interest, engagement, ease of use, self-paced learning, confidence, and acceptance. Responses were recorded on a five-point scale from 1 (strongly disagree) to 5 (strongly agree). Mean scores were interpreted using the intervals in Table 3.2. The survey had an overall Cronbach's alpha of .90 in the reported sample, indicating high internal consistency. Two items had one missing response ($n = 33$), which is shown in Table 4.3.

Table 3.2

Criteria for Interpreting the Means of the Perception Level

Likert-Scale	Likert Scale interval	Level of Interpretation	Level of Agreement
1	1.00 – 1.79	Very low	Strongly Disagree
2	1.80 – 2.59	Low	Disagree
3	2.60 – 3.39	Moderate	Neutral
4	3.40 – 4.19	High	Agree
5	4.20- 5.00	Very High	Strongly Agree

Note. Adapted from Pimentel (2019, p.188).

Semi-Structured Interviews

Six experimental-group students were purposively selected for face-to-face semi-structured interviews to obtain varied accounts of the perceived benefits and challenges of IVL-supported learning. The documented selection strategy ensured gender balance, with three male and three female participants, and required direct experience of the intervention. With consent, the interviews were audio-recorded and transcribed for analysis. A common interview guide was used across participants, with follow-up probes addressing conceptual understanding, engagement, pacing, narration, technical quality, and the support students required. The available study record does not document additional formal selection strata beyond gender and intervention experience, nor does it retain a reliable record of interview duration, interview language, or a separate translation protocol. Accordingly, those details are not inferred retrospectively.

Sampling and Participant Flow

The school was selected through convenience sampling, while intact class sections determined participation in the quasi-experimental strand. The survey was administered to the full experimental group. Interview participants were selected purposively from the experimental group because they had direct experience of the intervention and could describe its perceived benefits and challenges. Individual random assignment was not used.

The final analytic sample for the achievement-test comparisons comprised 68 students, with 34 students in each instructional condition. The perception survey was administered to the experimental group (n = 34), although two individual survey items each contained one missing response and are therefore reported with n = 33 in Table 4.3. The interview sample comprised six students drawn from the experimental group. Individual random assignment was not used. Because the available study file does not contain a complete stage-by-stage participant-flow log covering initial enrolment, consent, absences, intervention exposure, and assessment completion, the present report describes participant flow at the verified analytic stages and does not assign unverified reasons for exclusion or missingness.

Instrument Quality and Qualitative Trustworthiness

Physics specialists reviewed the survey items for clarity, relevance, and alignment before pilot testing. The final 22-item perception questionnaire demonstrated high internal consistency in the reported study sample, with Cronbach's alpha = .90. The archived study documentation does not preserve the pilot-sample size or a complete item-revision log following expert review and piloting. Consequently, the manuscript reports the expert-review procedure and the reliability evidence available for the final instrument without reconstructing undocumented pilot details.

Two subject experts evaluated the Physics Achievement Test for item relevance. The reported Scale-Level Content Validity Index based on universal agreement (S-CVI/UA) was .86, exceeding the stated .80 criterion. The achievement-test framework was aligned with the major electric-field content domains and with cognitive processes involving interpretation, application, explanation, and problem solving. However, the archived study documentation does not contain the item-level CVI values, detailed pilot item-analysis statistics, or a reliability coefficient for the final achievement scores. These statistics are therefore not retrospectively estimated. The reported S-CVI/UA should be interpreted as evidence of expert-assessed content relevance rather than as a substitute for item-level reliability evidence.

Table 3.3

Minimum Numerical Value of CVI

Number of Panel People	Minimum CVI Value
2	0.80
3	1.00
4	1.00
5	1.00
6	0.83
7	0.83
8	0.83
9	0.78
10	0.79

Subject experts reviewed the interview guide for language, clarity, coverage, and content relevance. Trustworthiness was strengthened through member checking, whereby transcripts or interpretive summaries were returned to participants to confirm the accuracy of representation. A second researcher reviewed the coding and emerging categories, and differences in interpretation were resolved through discussion and consensus after returning to the relevant transcript segments. Triangulation was undertaken by comparing achievement-test results, survey patterns, and interview themes. No dedicated qualitative-analysis software package or separate formal audit-trail procedure is documented in the available study file; therefore, the analysis is described in terms of the recorded transcript-based coding, researcher comparison, member checking, and cross-source triangulation procedures.

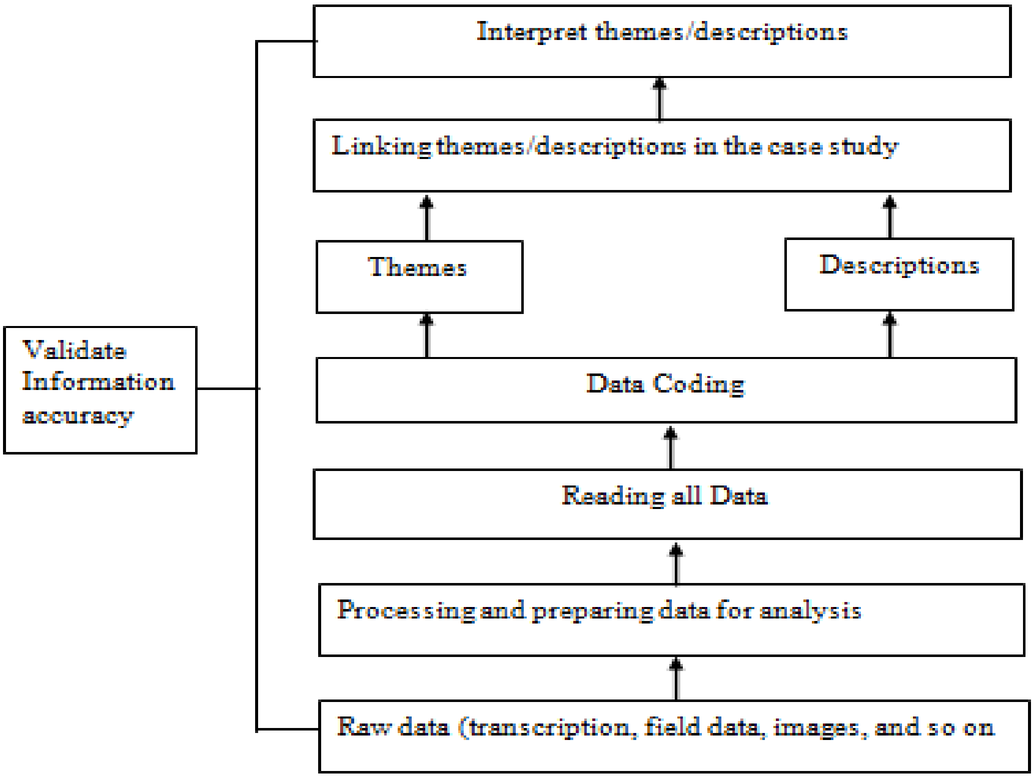
Data Analysis

Quantitative and qualitative data were analyzed separately and integrated during interpretation. Jamovi 2.6.26 was used for quantitative analysis. Integration involved comparing the direction and meaning of achievement-test results, perception-survey patterns, and interview themes to identify confirming, complementary, or divergent evidence.

Achievement scores were summarized using sample size and median because the reported score distributions did not support parametric analysis. Mann-Whitney U tests were used to compare independent groups at pre-test and post-test, and Wilcoxon signed-rank tests were used to assess paired pre-test-post-test change within each group. Rank-biserial correlation (r_rb) was reported as the effect-size measure; because its sign depends on group or time ordering, magnitude and direction were interpreted with the stated coding order. All reported inferential tests were two-sided and were interpreted at an alpha level of .05. The Mann-Whitney analysis assumes independent observations and, when interpreted as a location shift, similarly shaped distributions; the Wilcoxon analysis assumes paired observations and an approximately symmetric distribution of non-zero difference scores. The archived Jamovi summary available for manuscript revision does not retain the complete distributional-diagnostic output, the exact-versus-asymptotic test setting, software handling details for ties and zero differences, or 95% confidence intervals for the reported rank-biserial correlations. These quantities are therefore not reconstructed from summary statistics alone.

A direct between-group comparison of individual change scores (post-test minus pre-test) would provide the clearest statistical test of whether improvement differed between the experimental and control conditions. However, the student-level paired dataset was not contained in the archived materials available for this manuscript revision; consequently, group change-score medians and interquartile ranges, the corresponding Mann-Whitney U statistic, p value, rank-biserial correlation, and its confidence interval could not be recomputed without inventing results. The reported pre-test, post-test, and within-group analyses are therefore interpreted cautiously as preliminary evidence and are not presented as a definitive causal estimate of the intervention effect. Survey items were summarized using valid n, mean, and standard deviation. Interpretation followed the Table 3.2 intervals: very low (1.00-1.79), low (1.80-2.59), moderate (2.60-3.39), high (3.40-4.19), and very high (4.20-5.00).

Audio recordings were listened to repeatedly and transcribed before analysis. Each transcript was read in full, followed by line-by-line coding of meaningful units. Related codes were compared and grouped into broader categories, from which themes describing the perceived benefits and challenges of IVL-supported learning were developed. Themes were reviewed against the complete qualitative data set and refined through discussion between the researchers. A second researcher reviewed the coding and thematic structure, and disagreements were resolved through consensus based on the relevant transcript evidence. Member checking and comparison with perception-survey and achievement-test findings further supported credibility and triangulation.



Note. Adopted from the book by Creswell (2014, p. 247).

Ethical Considerations

The school administration provided written permission to use school resources and invite students to participate. Students were informed that participation was voluntary and that they could decline or withdraw before or during data collection without penalty. Written informed consent was obtained before data collection. The archived study file documents school authorization, voluntary participation, and informed consent but does not contain a separate record that permits verification of guardian-consent and student-assent procedures for any participant who may have been below the age of legal consent; no additional procedural claim is therefore made beyond the documentation available. Identifiers were removed, pseudonyms were used in qualitative reporting, and audio files and transcripts were handled confidentially.

RESULTS AND DISCUSSION

Effectiveness of IVL in Learning Electric Field Concepts

Pre-test scores were compared to examine baseline comparability. Both groups had a median of 0, and the Mann-Whitney test did not detect a statistically significant difference, $U = 542$, $p = .436$, $r_{rb} = -.062$. This small observed effect suggests little separation in the recorded pre-test scores, but a non-significant test does not prove equivalence or remove the selection risk associated with intact classes (Table 4.1).

At post-test, the experimental group recorded a median score of 14 compared with 8 for the control group. With groups ordered as control minus experimental, the Mann-Whitney test yielded $U = 304$, $p < .001$, $r_{rb} = -.474$, indicating a moderate separation of the post-test score distributions in the direction of higher experimental-group performance (Table 4.1). A 95% confidence interval for r_{rb} was not retained in the archived Jamovi summary and cannot be recovered reliably from the reported group-level statistics alone. The observed post-test difference is consistent with an advantage for the IVL condition; however, because the study used non-randomized intact classes and the direct between-group change-score analysis is unavailable, the result should be interpreted as preliminary evidence rather than as a definitive treatment effect.

Table 4.1

Results of Mann-Whitney Tests for Pre-Test and Post-Test Comparisons between CG and EG

Test	Groups	N	Median	Statistics(U)	p	r
	CG	34	0.00			
Pre-test				542	0.436	-0.0623
	EG	34	0.00			
	CG	34	8.0			
Post-test				304	<0.001	-0.474
	EG	34	14.0			

Note. Two-sided tests. CG = control group; EG = experimental group; r_rb = rank-biserial correlation. Group order was CG minus EG. The archived analysis output did not retain 95% confidence intervals for r_rb; therefore, confidence limits are not reported rather than retrospectively estimated.

Wilcoxon signed-rank tests indicated statistically significant pre-test-post-test improvement within both groups, W = 0.00, p < .001, r_rb = -1.00 under the reported time ordering (Table 4.2). The archived summary output did not retain the number of non-zero paired differences used in each test or 95% confidence intervals for the matched-pairs rank-biserial correlations. Improvement in both groups indicates that learning occurred under both instructional conditions. However, separate within-group significance tests do not establish that one group improved more than the other; consequently, these analyses are interpreted as evidence of within-group change rather than as a direct comparison of intervention effectiveness.

Table 4.2

Results of Wilcoxon Signed-Rank Tests for Pre-Test and Post-Test Comparisons within CG and EG

Control Group (CG)				Experimental Group (EG)		
	Post-test		**Pre-test**	**Post-test**		**Pre-test**
Median	8.00		0.00	14.00		0.00
W (34)		0.00			0.00	
p		<.001			<.001	
r		-1.00			-1.00	

Note. Two-sided paired tests. CG = control group; EG = experimental group; r_rb = matched-pairs rank-biserial correlation. Non-zero pair counts and 95% confidence intervals were not retained in the archived statistical output and are therefore not retrospectively estimated.

Students' Perceptions of Learning Electric Field Concepts Through IVL

Students expressed overwhelmingly positive perceptions of IVL, indicating high levels of interest, engagement, motivation, efficiency, and acceptance. Quantitative findings revealed consistently high means across core dimensions, such as interest (M = 3.75), engagement (M = 3.79), and efficiency (M = 3.80). The high rating for item-level indicators for example, relevance of IVL content (M = 4.24) and effectiveness of embedded questions (M = 4.00) further underscores students' recognition of IVL as a meaningful and enjoyable learning tool (see Table 4.3)

Table 4.3

Descriptive Statistics for each item

Sl. No	Items	N	M	SD	I
1	Interactive video lessons made learning more effective.	34	3.82	0.673	High

2	Interactive video lessons enhanced my interest towards learning physics.	34	3.91	0.621	High
3	I preferred to learn physics lessons using interactive video lessons.	34	3.59	1.048	High
4	Interactive video lessons were favorable for learning.	33	3.64	1.055	High
5	The use of interactive video lessons made my learning more enjoyable.	34	3.74	0.828	High
6	I liked interactive video lessons.	34	3.82	0.869	High
7	Interactive video lessons were easy to use.	34	3.85	0.821	High
8	I could ask questions during the interactive video lessons.	34	3.24	1.156	Moderate
9	Interactive video lessons increased my engagement.	34	3.65	0.95	High
10	Interactive video lessons helped me to remember the lessons better.	34	3.88	0.913	High
11	I could learn more from the interactive video lessons at my own pace.	34	3.71	1.001	High
12	I could answer the questions included in interactive video lessons.	34	4	0.778	High
13	I found interactive video lessons were relevant to the topic.	34	4.24	0.431	Very High
14	I could understand the concept of electric field better using interactive video lessons.	34	3.74	0.828	High
15	Interactive video lessons helped me perform better in physics.	34	3.24	0.987	Moderate
16	Interactive video lessons were useful for my learning.	34	3.97	0.674	High
17	The use of interactive video lessons improved my understanding of difficult topics.	33	3.82	0.95	High
18	I felt more confident in learning electric field through interactive video lessons.	34	3.65	0.812	High
19	Interactive video lessons helped me in improving my learning.	34	3.82	0.673	High
20	I recommend physics teachers to use interactive video lessons teach other physics related topics.	34	3.59	1.131	High
21	I believed that interactive video lessons in learning and teaching saved time.	34	3.76	1.017	High
22	Using interactive video lessons enhanced my understanding of electric field concepts.	34	3.85	0.657	High

These findings mirror international research indicating that interactive video environments enhance intrinsic motivation, engagement, and learning satisfaction (Kay, 2022; Merkt et al., 2011). The ability to pause, replay, and interact with embedded questions promotes self-regulated learning and sustained cognitive engagement, aligning with generative learning theory (Fiorella & Mayer, 2016). Students' qualitative reflections reinforced this interpretation: many attributed their improved understanding of Coulomb's law, inverse-square relationships, and electric field superposition to the video's visualizations and simulations.

Challenges Faced When Learning Electric Field Concepts Through IVL

Despite the overall positive evaluation, students identified several challenges associated with IVL use. These primarily involved issues of pacing, accent clarity, and audio quality. Some learners found the pace of explanation either too fast or inconsistent with their processing speed, highlighting the need for adjustable pacing features a recommendation consistent with multimedia design principles emphasizing learner control (Guo et al., 2014).

Accent clarity and sound quality were also reported as minor barriers that occasionally hindered comprehension. Such challenges are commonly cited in multimedia learning literature and emphasize the importance of high-quality narration and audio design for ensuring optimal comprehension and reducing cognitive load. Although these issues did not substantially diminish the overall learning experience, they represent critical considerations for the improvement of future IVL materials.

Most reported barriers concerned pacing, accent clarity, and audio quality; some students also indicated that abstract ideas were difficult to understand without teacher explanation. This finding supports the use of IVLs as a guided instructional resource rather than as a complete replacement for teacher scaffolding. Adjustable pacing, clearer narration, improved audio, and planned opportunities for questioning and debriefing may strengthen future implementation.

Implications

The findings of this study offer several important pedagogical and design implications for the effective integration of Interactive Video Lessons (IVLs) into physics education. Pedagogically, the results underscore the value of embedding IVLs within instructional practices, particularly for concepts that require the visualization of dynamic or abstract phenomena. To maximise their instructional potential, teachers may require structured professional learning in multimedia design to ensure that the IVLs they develop are both pedagogically sound and tightly aligned with curricular intentions. Furthermore, integrating interactive elements such as embedded prompts, guiding questions, and quizzes can sustain learner engagement and promote deeper conceptual processing, thereby enhancing the overall efficacy of physics instruction.

From a design and research standpoint, the study highlights the need for iterative refinement of IVL features to accommodate diverse learner needs. Future development should focus on adjustable pacing options, improved narration quality, and high-fidelity audio to ensure accessibility and clarity. Incorporating more sophisticated simulations and real-time feedback mechanisms may further bolster learners' conceptual understanding and performance outcomes. At the research level, expanding sample sizes and extending analyses across varied contexts will strengthen the generalizability of findings. Additionally, exploring the utility of IVLs as tools for formative and summative assessment including their capacity to track engagement and response patterns presents a promising avenue for empirical inquiry. Longitudinal studies will also be essential in elucidating the extended impact of IVL-supported learning on long-term retention and conceptual transfer.

LIMITATIONS

The findings should be interpreted within several methodological constraints. Participants were drawn from one school and remained in two intact Grade XII science sections, with one section assigned to each instructional condition. Individual randomization was not used; consequently, classroom clustering and possible section or teacher effects could not be separated fully from the intervention effect. The small, context-specific sample limits generalizability, and a non-significant pre-test comparison does not establish statistical equivalence. The archived analytical materials report pre-test, post-test, and within-group comparisons but do not contain the student-level paired data required to reconstruct a direct between-group change-score analysis or effect-size confidence intervals. In addition, the study record does not preserve complete session-level intervention dosage logs, detailed implementation-fidelity measures, item-level PAT validity statistics, or an achievement-test reliability coefficient. Survey responses were self-reported, and the qualitative strand involved six experimental-group students. These limitations require cautious interpretation of the findings as preliminary evidence and identify specific reporting and data-management priorities for future replication studies.

CONCLUSION

This study provides preliminary evidence that Edpuzzle-based IVLs can support students' learning of electric-field concepts when used in conjunction with teacher guidance. The experimental group recorded higher post-test achievement than the control group, and students generally described the IVLs as engaging, useful, and supportive of visualization and self-paced review. At the same time, pacing, narration, audio quality, and the need for teacher scaffolding emerged as important instructional design considerations. Because the study used two non-randomized intact classes and the archived analytical materials did not permit reconstruction of a direct between-group change-score analysis or effect-size confidence intervals, the findings should be interpreted as suggestive rather than definitive causal evidence. Within these limitations, IVLs appear to be a promising complementary resource for physics instruction, particularly for abstract concepts that benefit from visualization, repeated viewing, embedded questioning, and structured teacher debriefing.

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