Science Education International
35(2),163-172
https://doi.org/10.33828/sei.v35.i2.10

International Council of Association for Science Education

REVIEW ARTICLE

A Study on the Impact of Khan Academy Videos: Enhancing Grade 11 Thermodynamics Learning in a Rural High School

Nishaal Bhaw*, Rudorwashe Hungwe, Jeanne Kriek

Department of Physics, University of South Africa, Florida, South Africa

***Corresponding Author:** bhawn@unisa.ac.za

ABSTRACT

In the realm of science education, traditional teaching methods face challenges in catering to diverse learning preferences. This study investigates the efficacy of Khan Academy Videos (KAVs) in improving educational quality, specifically in rural thermodynamics instruction. The research involved 88 students and one teacher, with one group taught using traditional methods (control group [CG]) and the other using KAVs (experimental group [EG]). Results show significant improvements in learning outcomes and engagement with KAV integration, with EG scores improving by 61% compared to 31% in the CG. Pre-tests and post-tests were conducted to establish baseline understanding and measure academic performance, while a mixed-method approach analyzed results and feedback. Findings indicate that KAV integration positively influences student performance, offering valuable enhancements for resource-limited rural schools. This study underscores the transformative potential of KAV-integrated teaching in addressing educational challenges and elevating teaching quality.

KEY WORDS: Grade 11 thermodynamics; ideal gases and thermal properties; khan academy videos; mixed methods research; rural high school

INTRODUCTION

In recent years, educational technology has emerged as a powerful tool in transforming teaching and learning practices (Dwivedi et al., 2020). With the increasing availability of digital resources and online platforms, educators have been exploring innovative ways to enhance the learning experience for students (Haleem et al., 2022). Khan Academy Videos (KAVs) is an open educational resource offering free digital educational materials produced by experts, primarily available online (Ruggieri, 2020). This study investigates the influence of KAVs in thermodynamics pedagogy, specifically in the topic of *Ideal Gases and Thermal Properties*, contextualized at a rural high school. The significance of effective science education is crucial as it lays the foundation for future scientific literacy and critical thinking (Rudolph, 2024). However, students in rural schools often face challenges such as limited access to educational resources (Muremela et al., 2023), lack of exposure to modern teaching methods (Maniram, 2023), and socioeconomic disparities that affect their learning experiences (Shava, 2022). It is imperative to address these challenges by exploring innovative approaches that improve the quality of science education in such settings. Although other innovative approaches such as virtual labs (Govender, 2023), gamification (Titus and Ng'ambi, 2023), and adaptive learning platforms (Chisom et al., 2024), have advantages over KAVs, they may not be the best fit for every student and learning context. Educators should consider incorporating a variety of teaching techniques to meet the diverse needs and preferences of their students. The accessibility and minimal resource requirements of implementing KAVs in rural schools are the driving factors for using KAVs in the present study.

In rural education, innovative teaching methods in science have emerged as important conduits for bridging geographical and pedagogical divides (Elias and Mansouri, 2023). These innovative approaches transcend traditional classroom boundaries, capitalizing on modern advancements in technology and pedagogy to enhance the science learning experience for rural students (Cebrián et al., 2020). Feasible technologies for the rural setting encompass virtual field trips (Cheng, 2022), video conferencing (Bailey et al., 2022), and resource-efficient virtual labs (Lai et al., 2022), requiring only a visual display and pre-recorded content to accommodate potential internet limitations. Moreover, incorporating interactive multimedia resources, such as simulations and engaging educational videos, offers dynamic learning experiences tailored to various cognitive styles (Muir et al., 2022). A noteworthy avenue is the integration of KAVs in teaching, which can empower students with a repository of expert-curated educational content (Yassine et al., 2021), enabling immersive and self-paced exploration of scientific concepts, even in the absence of extensive physical resources (Bond, 2020).

KAV-integrated teaching offers a potential solution to these contextual challenges by providing accessible and interactive educational content (Francom et al., 2021). KAVs cover many topics and can be accessed at the student's pace, making them particularly valuable for self-directed learning and revision (Rueda-Gómez et al., 2023). In addition, the interactive nature of KAVs, coupled with the constructivist approach (Fitria et al., 2021) to teaching, allows students to construct knowledge actively, promoting deeper conceptual understanding (Yassine et al., 2021). The present study navigates the intersection of technology, pedagogy, and rural education through a combination of constructivist theory, mixed methods research design, and a comparison between traditional and KAV-integrated teaching. The contours of this investigation unearth the transformative potential of KAV-integrated teaching, shedding light on their influence on academic performance and teaching efficacy. The research questions framing the present study demarcate science education pedagogy through the lens of KAV-integrated teaching.

RESEARCH QUESTIONS

The present study delves into the impact of utilizing KAVs as a teaching tool, focusing on evaluating their influence on academic performance and teaching efficacy. The present study uses a mixed methods design to compare two distinct groups: A control group (CG) taught by traditional teaching methods and an experimental group (EG) taught by KAV-integrated teaching. Two research questions guide the exploration of KAVs' instructional utility:

1. How does KAV-integrated teaching affect academic performance?
2. To what extent does KAV-integrated teaching support teaching?

The present study comprehensively examines the potential impact of KAV-integrated teaching on academic performance in the context of Grade 11 rural science students on Ideal Gases and Thermal Properties. The context of this investigation is particularly pertinent in light of rural schools' challenges, such as limited access to supplementary educational resources, reduced exposure to advanced teaching methodologies, and constraints in teacher-student interaction due to larger class sizes. By analyzing the influence of KAV-integrated teaching on academic outcomes while considering the distinctive difficulties encountered in rural education settings, this study contributes valuable insights that have the potential to alleviate some of the challenges mentioned earlier. Through the lenses of students and teachers, this research sheds light on the transformative role that KAVs can play in enhancing science education in rural areas, thereby paving the way for more equitable and impactful learning experiences. Given the dynamic advancements in educational technology and their demonstrated potential to enrich science education, a review of the literature critically synthesizes recent research to elucidate the multifaceted impacts and possibilities inherent in integrating educational videos, particularly KAVs, to enhance teaching and learning experiences across diverse educational landscapes.

LITERATURE REVIEW

Educational technology has become a prominent tool in enhancing science education across various settings. Recent research has explored the integration of digital resources (Iyer, 2021; Khoza, 2021; Mosquera Feijóo et al., 2021), online platforms (Iyer, 2021; Jeffery et al., 2021), and multimedia content to support science learning (Iyer, 2021; Mbambo-Thata, 2021; Motaung and Dube, 2020). These studies have shown that well-designed educational technology can increase engagement, facilitate active learning, and improve students' understanding of complex scientific concepts. Incorporating educational videos into pedagogical practices has witnessed a progressive surge over the past decade (Bankar et al., 2023). This discernible trend underscores the significance of employing video materials for facilitating the process of teaching and learning. Numerous rationales have been advanced to elucidate the pivotal role of educational videos in knowledge acquisition. Advocates underscore the fundamental instructional utility of videos within flipped, blended, and online educational paradigms (Moore and Smith, 2012; Stockwell et al., 2015). In addition, Brame (2016) posits that maximizing the efficacy of videos as instructional tools hinges on considering three vital aspects by educators: Cognitive load optimization, promoting deep student engagement, and active learning-strategy cultivation.

Educational videos have emerged as potent instruments for addressing challenges inherent to problem-solving, motivation, and understanding intricate concepts (Box et al., 2017). Box et al. (2017) emphasize the diverse benefits of utilizing educational videos, including the enhanced ease of conveying intricate scientific information through visual accessibility, cost-effectiveness, positive impact on emotional well-being, and cognitive enrichment. Furthermore, Box et al. (2017) postulate that video utilization augments intellectual capacity for intricate problem-solving. Notably, user-generated online videos such as those found on YouTube, are readily accessible and easily downloadable. However, the challenge lies in establishing the veracity in their scientific rigor, which raises significant doubts about the reliability of these YouTube resources. Hurtado-Bermúdez and Romero-Abrio (2023) posit that video clips imbued with diverse aspects augment support, conceptual comprehension, and academic accomplishment. Analogously, Cruse (2007) observes that videos employed in classroom settings engender constructive impacts on conceptual clarity, academic achievement, and learner motivation. Putri and Kusairi (2021) concur with this perspective, contending that video integration bolsters the depth of conceptual understanding, a view also shared by Hapsari et al. (2019). Echoing this sentiment, Soltura (2021) asserts the potency of videos in the teaching-learning continuum, accentuating their role in fostering enhanced comprehension. Consequently, it is plausible to posit that the incorporation of KAVs catalyzes elevating the levels of conceptual comprehension.

Scholarly discourse on the efficacy of KAVs is discernible within extant literature. The research undertaken by Weeraratne and Chin (2018) interrogates the impact of KAVs on enhancing mathematics proficiency in Sri Lanka, yielding compelling findings. On average, KAVs engendered a substantial increase in raw and scaled test scores by 3.77 and 3.15% points, respectively. Standard scores exhibited an enhancement of 0.20 standard deviations above the mean test score, attesting to the efficacy of KAVs in augmenting mathematical competencies. Light and Pierson (2014) shed light on the Chilean context, where KAVs galvanized active engagement among students. Murphy et al. (2014) underscore the positive transformation in students' attitudes toward mathematics after KAV integration. Their 2-year exploration attests to a 32% increment in students' affinity for mathematics.

Furthermore, 45% of students acknowledged acquiring novel mathematical concepts through the self-paced modality inherent to KAVs. The body of research assessing the impact of KAVs on academic achievement in African contexts remains nascent (Light and Pierson, 2014); however, the Libraries Without Borders (2014) report documents preliminary findings from pilot projects. The initial analysis of KAV integration into 5th-grade curricula in Yaoundé, Cameroon, substantiates a 14% surge in academic performance and an even more impressive 36% elevation in creative competencies over a 3-month intervention period. Students evinced additional heightened self-confidence and enthusiasm for mathematical learning relative to peers in traditionally instructed settings.

A consensus emerges from various research endeavors, affirming students' heightened motivation and engagement through the integration of video materials (Murphy et al., 2014). Khan (2012) extols the pedagogical potency of KAVs, underscoring their efficacy in enabling real-time experiments even within resource-constrained contexts. The innovative problem-solving techniques embedded within these videos and instantaneous feedback mechanisms emerge as catalysts for enhanced learning outcomes (Mirana, 2016). Research on the effectiveness of KAVs in science education has indicated positive outcomes. Studies have found that KAVs can enhance student learning outcomes, promote self-directed learning, and provide flexible access to instructional content (Quan, 2020; Rueda-Gómez et al., 2023; Torres et al., 2022). In the rural school context, where access to educational resources and modern teaching methods can be limited, KAVs have been explored as a potential solution. Research has demonstrated that KAVs can mitigate rural students' challenges, such as lack of access to expert instruction and up-to-date learning materials (Harmon, 2021; Wargo and Hoke, 2022).

Integrating educational technology, such as KAVs, holds promise to transform science education in rural schools. While existing research has demonstrated the potential benefits of KAVs, further investigation is needed to understand their specific impact on teaching and learning in science, particularly in rural high school contexts. Notably, the present study takes on the distinctive challenge of assessing the influence of KAVs on the teaching a thermodynamics topic specifically tailored to Grade 11 students aged between 16 and 17 years. The nuanced approach of the present study adds significant value to the existing body of knowledge as it delves into an age group characterized by unique cognitive and learning characteristics while also considering the constraints and opportunities specific to rural educational settings.

The distinctive contribution of this research lies in its focus on understanding how KAVs can effectively shape the learning experiences of Grade 11 students, bridging the gap between theoretical concepts and their practical applications in the realm of thermodynamics. By delving into a topic within the curriculum of these students, the study aims to provide insights that are more directly applicable to their academic journey. Furthermore, this study's framing within the constructivist learning theory enhances its value. As Grade 11 students are in a critical phase of cognitive development, the constructivist approach, which emphasizes the active role of learners in constructing their understanding, aligns well with their learning needs and cognitive growth. The study's findings are poised to illuminate the specific pathways through which KAVs can facilitate this constructive learning process, offering educators and researchers actionable insights that can be applied to enhance the quality of science education in similar contexts.

CONCEPTUAL FRAMEWORK

Constructivist theory of learning posits that learning is an active and iterative process where individuals actively construct understanding through their engagement with new information and their connections to pre-existing knowledge (Mirana, 2016). The constructivist theory aligns with investigating the efficacy of KAVs as a pedagogical tool in the context of the present study. By embracing constructivist principles, the present study examines how students engage with KAVs and how this engagement impacts their academic performance.

The primary independent variable under scrutiny is the teaching method, manifesting as traditional teaching for the CG and KAV-integrated teaching for the EG. Through a quasi-experimental design, the study explores the influence of these teaching methods on dependent variables, such as pre-test and post-test scores, serving as indicators of student comprehension and knowledge acquisition. Student engagement is the mediating variable between teaching methods and learning outcomes, encapsulating students' active participation, interaction, and intrinsic motivation during the learning process. Moderating variables, namely, prior knowledge and learning styles, introduce an additional layer of complexity to the investigation. These variables acknowledge that individual differences in students' baseline understanding and preferred learning modalities might interact with the teaching methods to impact the learning outcomes.

In addition, the contextual factor of the rural setting is considered, acknowledging the unique challenges and opportunities associated with education in such environments. An intervening variable, time, acknowledges that the duration of exposure to each teaching method plays a role in shaping the depth of learning and student outcomes. Evaluation methods encompass pre- and post-questionnaires administered to teachers and students, capturing perspectives, attitudes, and expectations regarding the teaching methods. Furthermore, pre-test and post-test scores provide empirical measures of learning gains, while the Reformed Teaching Observation Protocol (RTOP) affords insights into implementing reformed teaching practices during classroom interactions. The mediating, moderating, intervening, and contextual factors are controlled variables in the present study.

Anticipated outcomes of the present study encompass improved academic performance in the EG exposed to KAVs, indicative of the platform's ability to engage students and facilitate comprehension. Expected differential engagement between the groups underscores the interactive nature of KAVs, potentially influencing students' enthusiasm and investment in the learning process. Furthermore, the study acknowledges the significance of teacher and student perspectives in gauging the effectiveness of the teaching methods. From an applied perspective, the present study has implications for educational practices in rural and non-rural settings. If KAV-integrated teaching proves effective, it could represent a valuable resource to enhance science education, particularly in contexts with limited resources. The study's findings also contribute to discussions surrounding technology integration in education policies, aiming to elevate learning outcomes and engagement in various educational environments. With this conceptual framework as the foundational basis, the subsequent section delves into the research design, methodologies, and analytical approaches employed to rigorously investigate the interactions between teaching methods, student engagement, and learning outcomes within the specific context of KAV-integrated science education.

METHODOLOGY

The present study aims to answer two research questions. First, the effect of KAV-integrated teaching on academic performance and the extent to which KAV-integrated teaching supports teaching.

Research Design

The study adopted a mixed-methods research design, which allowed for a comprehensive exploration of the research questions. The quantitative aspect involved pre-test and post-test assessments to measure academic performance, while the qualitative component utilized pre- and post-intervention questionnaires and classroom observations to gain in-depth perspectives on teaching practices and the impact of KAV integration.

Sample

The study focused on Grade 11 students and their Physical Sciences teacher at a rural high school in the Sekhukhune district of the Limpopo province in South Africa. The participants were selected based on the school's willingness to participate in the study and the availability of teachers willing to integrate KAVs into their teaching methods. The sample comprised 88 students and one teacher. The CG, comprising 45 students, was taught using traditional methods. The EG, comprising 43 students, was taught with KAVs.

Data Collection

To assess students' academic performance, pre-tests, and post-tests were conducted before and after the teaching intervention – the pre-test aimed to establish a baseline level of students' understanding of *Ideal Gases and Thermal Properties*. After the intervention, the same test was administered to both the CG and EG, which involved the traditional teaching of the CG and the KAV-integrated teaching of the EG. The tests were designed to align with the curriculum's prescribed thermodynamic concepts and covered the Grade 11 topic of *Ideal Gases and Thermal Properties*.

The achievement test underwent validation by four independent experts, including content and face validity checks, to ensure linguistic clarity and question suitability. Experts aligned the test with examination guidelines and CAPS aims. Their inputs encompassed time allocation (1 h) and a 40-point scale. The reliability of the pre-test and post-test was quantified numerically through the Cronbach reliability index, yielding a value of 0.843. Similarly, the teacher and learner questionnaires were validated through face and content validity, involving subject experts' feedback. Test-retest reliability involved a pilot school, with teachers and 21 learners participating and adopting the RTOP to gauge intervention-induced changes, with permission secured for its use. The reliability of the RTOP was established through independent observations by the researcher and a Physical Sciences teacher.

Reformed classroom observation protocol (RTOP)

The RTOP was developed to assess the quality of science instruction in classrooms that have adopted reformed teaching approaches, aiming to promote student engagement and active learning (Piburn and Sawada, 2000). The RTOP assesses lesson design, content knowledge, instructional strategies, and classroom environment. Using a scoring system ranging from 0 to 4, observers assign scores based on the presence or absence of specific teaching behaviors within each category. Following the observation, scores are totaled to generate an overall score reflecting the degree to which teaching practices align with inquiry-based, student-centered approaches. The RTOP score provides valuable feedback to teachers, highlighting areas of strength and areas for improvement, ultimately promoting reflective teaching practices and continual enhancement of student learning experiences in science education. In the present study, the RTOP is used to evaluate the teaching methods employed in CG and EG. This observation tool provided a structured framework to assess the extent to which the teaching practices aligned with constructivist principles. The RTOP facilitated the assessment of learner engagement, teacher facilitation, and the learner-centeredness level in the classroom.

Teacher and learner questionnaires

Questionnaires were administered to the Physical Sciences teacher and students to gather qualitative insights into their experiences with KAVs and their impact on teaching and learning. The teacher questionnaires sought to understand the teacher's perspectives on KAV's effectiveness, its integration into the curriculum, and its impact on students' engagement and conceptual understanding. The learner questionnaire aimed to elicit feedback on students' experiences with KAVs, their level of engagement, and their perceived impact on their academic performance and understanding of *Ideal Gases and Thermal Properties*.

Data Analysis

A mixed method approach analyzed the results of the tests and questionnaires. An independent samples *t*-test compared the CG and EG mean scores to determine any statistically significant differences in existing knowledge before the intervention. A paired samples *t*-test compared the mean scores of each group to determine any statistically significant differences in academic performance after the intervention. Data from the RTOP and questionnaires were analyzed thematically to identify patterns and themes related to teaching methods, learner engagement, and the affinity for integrating KAVs.

Ethical Considerations

Ethical approval, having reference number 2021/CSET/SOS/014, was obtained from the relevant institutional review board before conducting the study. Informed consent was obtained from all participants, including the school principal, the Physical Sciences teacher (Mr. G), and the students. Participants were assured of the confidentiality and anonymity of their responses, and they were free to withdraw from the study at any time without penalty.

Limitations

The present study encountered several limitations. The small sample size and the inclusion of only one rural high school limit the generalizability of the findings to other contexts. The limited teaching time also prevented a comprehensive exploration of KAV's influence on students' understanding. Compounded by the COVID-19 pandemic's effect on the school timetable, time constraints emerged for the intervention. It is important to note that the study focused on a specific Chemistry topic, which may not fully capture the broader impact of KAV integration in the science curriculum. However, despite these limitations, the study offers valuable insights into the potential benefits of KAVs in enhancing teaching and learning outcomes within a rural high school setting.

RESULTS

Lesson Plans

The Grade 11 topic of *Ideal Gases and Thermal Properties* comprises 11 subtopics and 21 objectives. The present study analyzed the three 60-min lessons and their corresponding lesson plans.

Test Scores

The present study first compared the performances of the EG and the CG to ensure their similarity before the teaching intervention. The pre-test and post-test scores for each group are summarized in Table 1.

The independent-sample *t*-test analysis showed no statistically significant difference in the pre-test scores between the two groups, suggesting that the students within each group were at the same level of achievement. The data in Table 1 show an increase in the mean test scores of both groups after the teaching intervention. The mean post-test score of the students exposed to KAVs ($M = 69.00$, $SD = 25.91$) was significantly higher than that of the students exposed to traditional teaching ($M = 37.83$, $SD = 7.57$) at the 0.05 level of significance ($p < 0.01$). A paired samples *t*-test assessed the relationship between pre-test and post-test scores within each group (Table 2).

Table 2 shows that traditional teaching intervention significantly improved academic achievement, as there was a significant difference between pre-test and post-test scores ($p < 0.001$). Similarly, for the EG, the KAV-integrated teaching intervention significantly improved academic achievement, with a significant difference between pre-test and post-test scores ($p < 0.001$). The more-than-double difference between the pre-test and post-test scores between the EG and the CG indicates that the KAV-integrated teaching intervention was more successful than the traditional teaching intervention. In addition to the t-test, the study calculated Hakes normalized gain (*g*; Hake, 1998) to measure the effectiveness of the intervention based on the improvement of conceptual understanding. The *g* values range between −1 and 1, with negative values indicating a decrease in students' scores after the intervention, signifying worse performance than before. *g* Value equalling zero suggests no improvement as students' scores remained the same.

On the other hand, *g* values greater than zero indicate that students' scores increased on the post-test, showing improvement. The *g* values calculated for the CG (0.415) are lower than the *g* values calculated for the EG (0.667). This observation seems to imply that the KAV-integrated teaching

Table 1: Independent-samples pre-test and post-test scores

Group	Intervention	n	M	SD	df	t	p-value
Pre-test							
Control	None	45	7.29	7.82	86.00	−0.53	0.60
Experimental	None	43	8.21	8.34			
Post-test							
Control	Traditional	45	38.07	7.57	86.00	7.66	0.00
Experimental	KAVs	43	69.00	25.97			

SD: Standard deviation, KAV: Khan academy video

Table 2: Dependent samples pre-test and post-test scores

Intervention	n	M	SD	Df	t	p-value
Control group						
None	45	7.290	7.820	44.000	−22.763	0.000
Traditional	45	38.070	7.570			
Experimental group						
None	45	8.210	8.340	86.000	−14.783	0.000
KAVs	43	69.000	25.970			

SD: Standard deviation, KAV: Khan academy video

approach effectively improved the Grade 11 students' conceptual understanding of *Ideal Gases and Thermal Properties*.

RTOP CG

Mr G taught three 60-min lessons to the CG, guided by lesson plans–the teaching resources used for all three lessons comprised handouts, a chalkboard, and a whiteboard. Table 3 shows the RTOP observations for the CG lessons.

The RTOP observations indicate that the teacher has a solid grasp of the content pertaining to Boyles Law and Charles Law. Further observations from Lesson 1 underscore that, despite successfully covering all intended content, lesson objectives were challenging, as evidenced by students' struggles to answer follow-up questions. The struggle was accompanied by notably low levels of participation and engagement, coupled with an overarching teacher-centered discourse. Furthermore, student comprehension obstacles led to an insufficient grasp of certain concepts, a trend that persisted across the subsequent lessons. In Lesson 2, a similar pattern emerged, with the coverage of all content yet a shortfall in fully achieving lesson objectives. Notably, low participation levels, compounded by limited performance during class activities, accentuated the learning barriers. The application aspect of Boyle's law posed particular challenges, as evidenced by students' inaccurate responses during feedback exercises. The teacher-centered nature of the lesson further indicates room for improvement in terms of interactive engagement and student-centered approaches. Lesson 3 illustrated the prevalence of teacher-centered instruction, with students encountering difficulties comprehending some explanations. Despite comprehensive coverage of content, the achievement of lesson objectives remained incomplete. These observations were reinforced by students' struggles with class activities, indicating a misalignment between instructional objectives and outcomes. During class discussions on applications of Charles' law, students faced substantial challenges, resulting in limited response rates. Low participation levels and delayed concept assimilation were further evident in this lesson, as highlighted by the extended time required for concept explanations.

RTOP EG

Mr G taught three 60-min lessons to the EG using KAV-integrated teaching, guided by lesson plans and teaching resources used for all lessons in the EG comprised of laptops, smartphones, tablets, an LCD projector, and a projector screen. Table 4 shows the RTOP observations for the EG lessons.

Table 4 shows that in Lesson 1, students were notably immersed in the learning process, exhibiting high levels of participation and concentration during the KAV sessions. Mr. G skillfully orchestrated a learner-centered approach by setting clear yet challenging objectives, which were effectively communicated at the beginning of each activity. This approach culminated in achieving all set objectives, evident through the high-performance levels of in-class activities. In addition, Mr. G's encouragement and recognition of excellent performance fostered a positive learning environment. However, technical challenges necessitated using projector screens for KAVs due to low battery outputs on some devices. Lesson 2 and Lesson 3 maintained this momentum of engagement and achievement, with students actively participating, responding accurately to questions, and demonstrating a profound understanding of the content. Mr. G's dynamic teaching strategies and motivational presence were evident throughout the lessons. The continuous movement around the classroom in Lesson 3 further ensured the involvement and progress of all students. In conclusion, the RTOP analysis underscores Mr. G's effective learner-centered approach, fostering high levels of engagement and successful attainment of lesson objectives across the observed sessions.

The cumulative analysis underlines the need for a more balanced approach to teaching, encompassing greater student engagement and interactive learning strategies. The persistent prevalence of teacher-centered discourse and students' struggles grasping certain concepts advocates for tailored interventions that enhance concept comprehension and participatory engagement. This analysis highlights the potential of alternative teaching methods, such as the integration of KAVs, to address the observed challenges and contribute to more effective learning outcomes.

DISCUSSION

The present study's findings are contextualized by the RTOP, questionnaires, and literature review framed by the conceptual framework.

How does KAVs Integrated Teaching Affect Academic Performance?

The CG pre-test scores ($n = 45$, $M = 7.29$, $SD = 7.82$) and EG pre-test scores ($n = 43$, $M = 8.21$, $SD = 8.34$) are not statistically

Table 3: RTOP ratings control group lessons

S	RTOP section category																								
	D					E					F					G					H				
	Rating					Rating					Rating					Rating					Rating				
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
Lesson 1																									
1				x						x				x					x					x	
2				x				x						x					x					x	
3				x					x						x			x					x		
4			x							x				x					x				x		
5			x						x						x			x						x	
Lesson 2																									
1				x						x				x					x						x
2				x				x					x					x						x	
3				x						x			x					x					x		
4		x							x					x				x						x	
5		x							x					x				x						x	
Lesson 3																									
1			x							x				x					x					x	
2			x					x						x				x					x		
3		x								x			x					x					x		
4			x						x					x					x					x	
5			x						x				x					x						x	

C: Lesson Design and Implementation. D: Content: Propositional Pedagogic Knowledge. E: Content: Procedural Pedagogic Knowledge. F: Classroom Culture: Communicative Interactions. G: Classroom Culture: Student/teacher Relationships. S: RTOP Criteria Statement, RTOP: Reformed teaching observation protocol

Table 4: RTOP observation ratings experimental group lessons

S	RTOP Section Category																								
	C					D					E					F					G				
	Rating					Rating					Rating					Rating					Rating				
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
Lesson 1																									
1				x						x				x					x						x
2					x					x				x						x					x
3					x					x					x					x					x
4					x					x				x						x					x
5					x					x					x					x					x
Lesson 2																									
1					x					x					x				x						x
2					x					x				x						x					x
3					x					x					x					x					x
4					x					x					x					x					x
5					x					x				x						x					x
Lesson 3																									
1				x						x				x					x						x
2					x					x				x						x					x
3					x					x					x					x					x
4					x					x				x						x					x
5					x					x					x					x					x

C: Lesson Design and Implementation. D: Content: Propositional Pedagogic Knowledge. E: Content: Procedural Pedagogic Knowledge. F: Classroom Culture: Communicative Interactions. G: Classroom Culture: Student/teacher Relationships. S: RTOP criteria statement, RTOP: Reformed teaching observation protocol different ($t = -0.53$ and $p = 0.60$). However, the CG post-test scores ($n = 45$, $M = 38.07$, $SD = 7.57$) and EG post-test scores ($n = 43$, $M = 69.00$, $SD = 25.97$) indicate that there was a statistically significant difference in academic performance between the two groups ($t = -0.53$ and $p < 0.005$). An analysis of the pre-test and post-test revealed an improved performance in the EG compared to the CG. The findings suggest that KAV integration significant influences the performance of Grade 11 students on *Ideal Gases and Thermal Properties*. Although the CG scores improved by 30.78%, the improvement in the EG scores was almost twice that of the CG (60.79%). This finding is consistent with the literature reviewed. Light and Pierson (2014) noted that videos enhance learners' academic performance and problem-solving. As videos increase intellectual capacity levels (Box et al., 2017), they confirm students' achievement test performance. In support of the findings, improved levels of performance in the pre- and post-test by participants who were exposed to KAVs when compared to participants exposed to traditional teaching methods were confirmed by other researchers (Barman, 2013; Light and Pierson, 2014; Weeraratne and Chin, 2018).

To What Extent does KAV-Integrated Teaching Support Teaching?

The RTOP analysis revealed that KAV integration positively influenced teaching of Grade 11 *Ideal Gases and Thermal Properties*. KAVs function as an educational tool that supports students in the process of knowledge acquisition. Mr. G's approach to teaching was different for the CG and the EG. Students in the EG were actively involved in the learning process, predicting, discussing, and explaining concepts with the teacher's assistance. Students' level of participation was high in the EG. Lotulung (2023) asserts that a good lesson is characterized by active participation or engagement by students. There were high levels of learner engagement during Mr. G's lessons using KAVs. More so, students could pause and replay the KAVs to conceptualize knowledge. All the lesson contents for the EG were completed as planned. The lessons encouraged students to seek other ways of acquiring knowledge using KAV as a technological tool with less teacher talk.

It is important to note that students were actively engaged during the learning process. Light and Pierson (2014) affirm that KAVs have been designed to maximize students' engagement because they offer an opportunity to appeal to the cognitive load and actively engage the learner. In addition, the level of motivation was high in the EG, which is attributable to KAVs. Students were actively engaged in thought-stimulating activities from KAVs that often entailed critical assessment of procedures. Students communicated their scientific ideas with others, and the teacher used the videos to promote active participation. Integrating KAVs enhanced greater communication among students in the EG, thus promoting a learner-centered environment. A review of relevant literature suggests that effective teaching and learning involve appropriate teaching strategies that promote active engagement of students (Muir et al., 2022). The findings suggest that the teachers' learning environment and teaching approach in the EG resulted in high levels of conceptual understanding. As such, this is supported by Hurtado-Bermúdez and Romero-Abrio (2023) and Putri and Kusairi (2021), who assert that integration of modern technology in the teaching and learning process has great potential to ensure logical flow of lessons and grasping of concepts. Teaching thermodynamics using KAVs proves that technology offers a straightforward means to depict intricate concepts.

Evidence suggests that students in the CG faced challenges in grasping concepts during traditional teaching and heavily relied on Mr. G's explanations as he determined the lesson's focus and direction. Fitria et al. (2021) argue that a learner-centered approach promotes knowledge acquisition levels and academic performance. Murphy et al. (2014) state that a good lesson can motivate students. In light of these claims, the level of motivation in the EG when teaching integrated KAVs was high. In addition, all three lessons taught by Mr. G in the EG promoted active participation. These findings support the positive influence of KAV-integrated teaching of Grade 11 thermodynamic concepts.

The present study finds that KAV integration positively influences teaching and learning. This finding is supported by Shava (2022), who believes that the teaching and learning processes can be successful and effective for the learner by integrating ICT into teaching. The post-intervention questionnaire analysis also revealed that teachers and students strongly support the use of KAVs in the teaching process. Integrated KAV teaching allows students to watch KAVs at their pace and share and communicate ideas. There is overwhelming support from teachers and students for KAV integration. Another finding is that KAV-integrated teaching positively influences students' level of conceptual understanding. According to (Mirana, 2016), significant levels of conceptual understanding indicate an effective teaching process. These findings are consistent with Hapsari et al. (2019) and Soltura (2021) and support the claim that KAV-integrated teaching is more effective than traditional teaching methods, even in resource-poor rural schools in South Africa.

The findings of the present suggest that KAVs enable effective teaching by providing teachers with valuable resources to create learner-centered environments and facilitate active participation. The use of technology in rural schools is particularly beneficial, as it offers access to quality educational content, even in resource-limited settings.

Implications of the Study

The present study's findings have several implications for education, especially in the context of rural schools. The positive influence of KAV-integrated teaching on students' academic performance and conceptual understanding underscores its potential as an effective educational tool. By leveraging technology, educators can foster more engaging and interactive learning experiences for students, even in schools with limited resources. The study also highlights the significance of adopting constructivist teaching approaches, where students actively participate in the knowledge-construction process. Integrating KAVs into the classroom aligns well with this approach, promoting deeper conceptual understanding and critical thinking skills among students.

Moreover, the findings suggest the importance of providing adequate training and support to teachers for effectively integrating KAVs in the classroom. Teachers must have the necessary skills and knowledge to leverage tools like KAVs to enhance their teaching practices and create dynamic learning environments. The successful integration of KAVs in teaching during the COVID-19 era further highlights its potential in ensuring uninterrupted education. Technology-based learning resources like KAVs can bridge the gap and enable continuous learning during disruptions or limited access to physical classrooms. However, teacher interaction is essential and technology integration must be viewed as an enhancement to teaching rather than a replacement of teachers.

Overcoming Challenges and Recommendations for Future Research

Despite the positive findings, the present study also identified certain challenges that need to be addressed to maximize the potential of KAV integration in rural schools. One of the key challenges is the lack of reliable internet connectivity and access to digital devices in rural areas. To fully leverage the benefits of KAV-integrated teaching, adequate infrastructure must be provided to ensure smooth access to educational resources. Policymakers and educational institutions must prioritize investments in digital infrastructure to bridge the digital divide and ensure equitable access to educational opportunities for all students.

Another challenge is the limited time allocated for KAV-integrated teaching. The 1-week intervention in the present study may have influenced the depth of its impact on students. Future research should explore the effects of longer-term KAV integration to assess its sustained influence on students' academic performance and engagement. In addition, the study recognizes that focusing on one topic within thermodynamics limits the generalization of the findings to other subject areas. Future studies should expand the investigation to cover various topics in the science curriculum to gain a more comprehensive understanding of KAV's impact on learning outcomes.

While the present study provides valuable insights into the influence of KAV-integrated pedagogy specific to Grade 11 thermodynamics, there are several avenues for future research. A longitudinal study to assess the long-term impact of KAV integration on students' academic performance and conceptual understanding would provide a more comprehensive understanding of its effectiveness. Exploring diverse subject areas and topics within the science curriculum would allow for a broader assessment of KAV's potential across various educational contexts. A larger sample size to include multiple schools and regions would enhance the generalizability of the findings and provide a more diverse perspective. From the teacher's perspective, conducting in-depth training programs for teachers on the effective use of KAVs and other educational technologies would empower educators to maximize their benefits in the classroom. In-depth training will combine well with the learner's perspective by exploring the impact on students' practical-related skills and laboratory work. These perspectives shed light on its potential to enhance hands-on learning experiences.

CONCLUSION

The study highlights the positive influence of KAVs on teaching and learning Grade 11 thermodynamics in a rural high school. KAV-integrated teaching and constructivist teaching methods improved academic performance, enhanced problem-solving skills, and increased learner motivation and interest in the subject matter. However, challenges such as limited infrastructure and time constraints must be addressed to maximize the potential of educational technology in rural schools. By prioritizing digital literacy, providing professional development for teachers and investing in digital infrastructure, educational institutions can create a conducive environment for effective technology integration and foster enhanced learning outcomes in resource-poor settings. The present study's findings contribute to the growing body of research on technology integration in education and emphasize the importance of leveraging educational technology to bridge educational gaps and promote equitable access to quality education for all students.

ACKNOWLEDGMENT

The content of this paper is based on the MSc study of Rudorwashe Hungwe under the supervision of Prof. Jeanne Kriek.

REFERENCES

Bailey, D.R., Almusharraf, N., & Almusharraf, A. (2022). Video conferencing in the E-learning context: Explaining learning outcome with the technology acceptance model. *Education and Information Technologies*, 27(6), 7679-7698.

Bankar, M.N., Bankar, N.J., Singh, B.R., Bandre, G.R., & Shelke, Y.P. (2023). The role of E-content development in medical teaching: How far have we come? *Cureus*, 15(8), e43208.

Barman, N. (2013). *An Evaluation of the Effectiveness of the Khan Academy Videos for Teaching Mathematics at Menzi High School*. Independent Study Project Collection. 1501.

Bond, M. (2020). Facilitating student engagement through the flipped learning approach in K-12: A systematic review. *Computers and Education*, 151, 103819.

Box, M.C., Dunnagan, C.L., Hirsh, L.A.S., Cherry, C.R., Christianson, K.A., Gibson, R.J., Wolfe, M.I., & Gallardo-Williams, M.T. (2017). Qualitative and quantitative evaluation of three types of student-generated videos as instructional support in organic chemistry laboratories. *Journal of Chemical Education*, 94(2), 164-170.

Brame, C.J. (2016). Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE-Life Sciences Education*, 15(4), es6.

Cebrián, G., Junyent, M., & Mulà, I. (2020). Competencies in education for sustainable development: Emerging teaching and research developments. *Sustainability*, 12(2), 579-587.

Cheng, K.H. (2022). Teachers' perceptions of exploiting immersive virtual field trips for learning in primary education. *Journal of Research on Technology in Education*, 54(3), 438-455.

Chisom, O.N., Unachukwu, C.C., & Osawaru, B. (2024). Review of AI in education: Transforming learning environments in Africa. *International Journal of Applied Research in Social Sciences*, 5(10), 637-654.

Cruse, E. (2007). *Using Educational Video in the Classroom: Theory, Research and Practice Multimodal Learning Styles Dual-channel Learning Motivation and Affective Learning*. Available from: https://api.semanticscholar.org/corpusid:14027419 [Last accessed on 2023 Aug 22].

Dwivedi, Y.K., Hughes, D.L., Coombs, C., Constantiou, I., Duan, Y., Edwards, J.S., Gupta, B., Lal, B., Misra, S., Prashant, P., Raman, R., Rana, N.P., Sharma, S.K., & Upadhyay, N. (2020). Impact of COVID-19 pandemic on information management research and practice: Transforming education, work and life. *International Journal of Information Management*, 55, 102211.

Elias, A., & Mansouri, F. (2023). Towards a critical transformative approach to inclusive intercultural education. *Journal of Multicultural Discourses*, 18(1), 4-21.

Fitria, D., Jamaris, J., & Sufyarma, M. (2021). Implementation of constructivism learning theory in science. *International Journal Of Humanities Education and Social Sciences*, 1(3), 228-235.

Francom, G.M., Lee, S.J., & Pinkney, H. (2021). Technologies, challenges and needs of K-12 teachers in the transition to distance learning during the COVID-19 pandemic. *TechTrends*, 65(4), 589-601.

Govender, R. (2023). Teaching and learning using virtual labs: Investigating the effects on students' self-regulation. *Cogent Education*, 10(1), 2172308.

Hake, R.R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74.

Haleem, A., Javaid, M., Qadri, M.A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3, 275-285.

Hapsari, A.S., Muhammed, H., Gunarhadi, M.A., & Roemintoyo, H. (2019). Motion graphic animation videos to improve the learning outcomes of elementary school students. *European Journal of Educational Research*, 8(4), 1245-1255.

Harmon, H. (2021). Innovating a promising practice in high poverty rural school districts. *The Rural Educator*, 41(3), 26-42.

Hurtado-Bermúdez, S., & Romero-Abrio, A. (2023). The effects of combining virtual laboratory and advanced technology research laboratory on university students' conceptual understanding of electron microscopy. *Interactive Learning Environments*, 31(2), 1126-1141.

Iyer, L.M. (2021). A self-study of pedagogical experiences in history education at a university during the COVID-19 pandemic. *Yesterday and Today*, 2(24), 92-112.

Jeffery, A.J., Rogers, S.L., Jeffery, K.L.A., & Hobson, L. (2021). A flexible, open, and interactive digital platform to support online and blended experiential learning environments: Thinglink and thin sections. *Geoscience Communication*, 4(1), 95-110.

Khan, S. (2012). *The One World Schoolhouse: Education Reimagined*. New York: Twelve.

Khoza, S.B. (2021). Exploring the migration to a digitalised curriculum at UKZN. *Education Sciences*, 11(11), 682-698.

Lai, T.L., Lin, Y.S., Chou, C.Y., & Yueh, H.P. (2022). Evaluation of an inquiry-based virtual lab for junior high school science classes. *Journal of Educational Computing Research*, 59(8), 1579-1600.

Libraries Without Borders. (2014). *Transforming Education - Intermediate Study*. London: Libraries without Borders.

Light, D., & Pierson, E. (2014). Increasing student engagement in math: The use of Khan Academy in Chilean classrooms. *International Journal of Education and Development Using ICT*, 10(2), 103-119.

Lotulung, M. (2023). Highschool student engagement in active learning classrooms. *Journal on Education,* 5(2), 2729-2741.

Maniram, R. (2023). Recounting the learning challenges experienced by students from rural areas in South Africa in the context of a pandemic. *African Journal of Inter/Multidisciplinary Studies*, 5(1), 1-12.

Mbambo-Thata, B. (2021). Responding to COVID-19 in an African university: The case the National University of Lesotho library. *Digital Library Perspectives*, 37(1), 28-38.

Mirana, V. (2016). Effects of Computer Simulations and Constructivist Approach on Students' Epistemological Beliefs, Motivation and Conceptual Understanding in Physics. In: *International Conference on Research in Social Sciences, Humanities and Education* (*SSHE-2016*). Cebu, Philippines, pp. 89-93.

Moore, A.W., & Smith, R.A. (2012). Effects of video podcasting on psychomotor and cognitive performance, attitudes and study behaviour of student physical therapists. *Innovations in Education and Teaching International*, 49(4), 401-414.

Mosquera Feijóo, J.C., Suárez, F., Chiyón, I., & Alberti, M.G. (2021). Some web-based experiences from flipped classroom techniques in AEC modules during the COVID-19 lockdown. *Education Sciences*, 11(5), 211-229.

Motaung, L.B., & Dube, B. (2020). WhatsApp messenger as a mediating tool in times of COVID-19 for enhancing student engagement in e-tutorials at a rural South African university. *Journal of Educational and Social Research*, 10(6), 214-224.

Muir, T., Wang, I., Trimble, A., Mainsbridge, C., & Douglas, T. (2022). Using interactive online pedagogical approaches to promote student engagement. *Education Sciences*, 12(6), 415-432.

Muremela, G., Kutame, A., Kapueja, I., & Adigun, O.T. (2023). Retaining scarce skills teachers in a South African rural community: An exploration of associated issues. *African Identities*, 21(4), 743-759.

Murphy, R., Gallagher, L., Krumm, A.E., Mislevy, J., & Hafter, A. (2014). *Research on the Use of Khan Academy in Schools: Implementation Report*. Menlo Park: SRI International.

Piburn, M., & Sawada, D. (2000). *Reformed Teaching Observation Protocol (RTOP): Reference Manual*. ACEPT Technical Report No. IN00-3.

Putri, H.N.P.A., & Kusairi, S. (2021). The Impact of Learning with the Video Conceptual Understanding Coach toward Student Conceptual Understanding Force Concept. In: *The 4th International Conference on Mathematics and Science Education (ICOMSE) 2020: Innovative Research in Science and Mathematics Education in the Disruptive Era*, p. 050025.

Quan, X. (2020). Learning to learn - A potential educational focus during and post the COVID-19 pandemic. *Advances in Engineering Education*, 8(4), 1-8.

Rudolph, J.L. (2024). Scientific literacy: Its real origin story and functional role in American education. *Journal of Research in Science Teaching*, 61(3), 519-532.

Rueda-Gómez, K.L., Rodríguez-Muñiz, L.J., & Muñiz-Rodríguez, L. (2023). Performance and mathematical self-concept in university students using Khan Academy. *Heliyon*, 9(4), e15441.

Ruggieri, C. (2020). Students' use and perception of textbooks and online resources in introductory physics. *Physical Review Physics Education Research*, 16(2), 020123.

Shava, E. (2022). Reinforcing the role of ICT in enhancing teaching and learning post-COVID-19 in tertiary institutions in South Africa. *Journal of Culture and Values in Education*, 5(1), 78-91.

Soltura, R.T. (2021). Designing context-based video instruction in enhancing the conceptual understanding of Grade XI students. *Indonesian Journal of Educational Research and Review*, *4*(3), 409-423.

Stockwell, B.R., Stockwell, M.S., Cennamo, M., & Jiang, E. (2015). Blended learning improves science education. *Cell*, 162(5), 933-936.

Titus, S., & Ng'ambi, D. (2023). Digital gaming for cross-cultural learning: Development of a social constructivist game- based learning model at a South African University *International Journal of Game-Based Learning*, 13(1), 1-20.

Torres, D., Pulukuri, S., & Abrams, B. (2022). Embedded questions and targeted feedback transform passive educational videos into effective active learning tools. *Journal of Chemical Education*, 99(7), 2738-2742.

Wargo, E., & Hoke, I. (2022). Revisiting rural education access. *Educational Considerations*, 48(2), 1-10.

Weeraratne, B., & Chin, B. (2018). Can Khan Academy e-learning video tutorials improve mathematics achievement in Sri Lanka? *International Journal of Education and Development Using Information and Communication Technology*, 14(3), 93-112.

Yassine, S., Kadry, S., & Sicilia, M. (2021). Application of community detection algorithms on learning networks. The case of Khan Academy repository. *Computer Applications in Engineering Education*, 29(2), 411-424.