

Multimedia-integrated physics instruction: Impact on student engagement in Tanzanian secondary schools

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Abstract. This study investigates the impact of multimedia integration on student attitudes and engagement in physics education in Tanzanian secondary schools. A convergent mixed-methods case study was conducted in four government schools in Mbeya Region with 96 Form Two students and two physics teachers. Grounded in Mayer's cognitive theory of multimedia learning and Vygotsky's social constructivism, the eight-lesson intervention used PhET simulations, videos, and animations on sustainable energy sources. Students' attitudes shifted from neutral ($M = 2.89$) to strongly positive ($M = 4.86$) on a 5-point scale, a statistically significant improvement ($t = 41.18$, $df = 95$, $p < .001$). Qualitative data revealed enhanced interest, motivation, confidence, real-world relevance perception, career interest, and classroom participation. Teachers observed increased engagement from previously disengaged students. Limitations include the four-week intervention period and restriction to four schools in one district, which constrain generalisability. Evidence-based recommendations are offered for integrating multimedia into physics education in Tanzanian secondary schools.

Keywords: multimedia integration, physics instruction, physics education, learning engagement, secondary education

1. Introduction

Physics subject knowledge is applied in a variety of fields including communication, health, transportation, environmental conservation, scientific civil service, engineering, alternative energy, industries, and computing. Generally, physics cultivates analytical and problem-solving skills essential for the modern workforce [2]. However, students find the subject challenging and difficult to learn [2]. This stems from traditional, teacher-centred instructional methods and passive learning, hampered by a lack of appropriate instructional materials and resources that can facilitate deeper understanding [2]. Traditional teaching methods often fail to engage students actively, especially in physics, which is frequently perceived as abstract and challenging. The complexity of physics requires innovative teaching approaches. Ahmed and Asiksoy [3] state that teaching physics demands innovative approaches to engage students effectively. Verawati and Nisrina [50] assert that innovative pedagogical strategies are vital for fostering not only interest but also a deeper understanding of complex scientific concepts. Muhomi and Mbise [31] observed that in Tanzania, students in secondary schools experience poor understanding of science concepts, caused by a lack of appropriate teaching aids to demonstrate complex concepts. This has also been associated with students' negative attitudes towards physics.

Physics education in Tanzania suffers from teacher-centred methods and insufficient instructional materials, leading to poor conceptual understanding and negative attitudes [31]. Multimedia integration – particularly videos and animations aligned with Mayer's cognitive theory of multimedia learning – addresses this by reducing cognitive load while enhancing self-efficacy [56] and improving conceptual understanding [7, 8]. However, most Tanzanian teachers still rely on lecture-based

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Received	Accepted	Published	Version of record
2026-01-20	2026-04-08	2026-10-25	2026-10-25



Science
Education
Quarterly



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methods [21, 34], and few studies have examined multimedia's impact on student attitudes and engagement in Tanzanian physics classrooms [2, 28]. This study addresses that gap by investigating how multimedia integration affects student attitudes and engagement in Tanzanian secondary school physics, using a mixed-methods case study in four Mbeya Region government schools.

Student engagement is the degree of active involvement, interest, and commitment a student exhibits in their learning process [24, 25]. In academic contexts, engagement comprises three dimensions: cognitive, emotional, and behavioural engagement. Cognitive engagement involves the mental effort students apply to understand complex concepts and engage in critical thinking [24, 25]. Emotional engagement reflects positive feelings such as curiosity, interest, or a sense of belonging within the learning environment, fostering a deeper connection to the material [35]. Behavioural engagement is characterised by active participation, including consistent attendance, timely task completion, and meaningful interactions with peers and instructors [15].

In Tanzania, the educational system strives to improve quality through technology integration and STEM education, as reflected in the Ministry of Education's strategic plans [49]. However, Nyirahabimana et al. [34] note that most instructors face challenges in utilising multimedia resources effectively, leading to diminished engagement among students. This highlights a critical gap in understanding how multimedia can be systematically implemented to enhance learning experiences in secondary schools.

This study addresses the main research question: *How does the integration of multimedia tools in physics instruction impact students' attitudes and engagement towards learning physics in Tanzanian secondary schools?* The study was specifically driven by the following research questions:

1. What is the effect of multimedia-integrated physics instruction on students' attitudes towards physics learning?
2. What is the impact of multimedia-integrated physics instruction on students' learning engagement?

2. Theoretical framework for the study

This study employs two theoretical frameworks: Mayer's cognitive theory of multimedia learning (CTML) and Vygotsky's social constructivism. CTML guided the multimedia design to maximise learning outcomes, while social constructivism informed the creation of an appropriate learning environment.

Richard Mayer's cognitive theory of multimedia learning posits that students achieve better learning outcomes when visual and auditory elements are integrated rather than relying solely on text [30]. CTML emphasises dual-channel processing (visual and auditory), limited cognitive capacity, and the necessity for active engagement in meaningful learning. By integrating videos and animations, this study investigated how complex physics concepts could be simplified by aligning with CTML principles. Careful consideration was given to minimising extraneous cognitive load, presenting essential content clearly, and encouraging students to actively construct understanding by integrating new information with prior knowledge. This alignment addresses instructional challenges and improves learner engagement and comprehension in physics classrooms. While cognitive outcomes such as retention and transfer are direct measures of learning under CTML, Weerasinghe, Lalitha and Fernando [53] argue that affective outcomes including satisfaction and engagement should also be considered, as they significantly influence the learning process. Cavanagh and Kiersch [11] demonstrate that CTML principles extend beyond cognitive gains to shape learners' affective responses to instructional materials. Specifically, attention-grabbing multimedia elements are more likely to be perceived as enjoyable and can generate desirable affective reactions to the lesson [40]. These findings underscore the importance of designing multimedia instruction that supports cognitive processing while fostering positive attitudes and sustained engagement.

Vygotsky's social constructivism [51] emphasises that knowledge is co-constructed through social interaction and experiential learning. This is particularly relevant to multimedia integration in

Tanzanian physics education, where collaborative opportunities are constrained by resources and traditional methods. Social constructivism advocates learning environments promoting dialogue, practical activities, and group work, enabling students to co-construct knowledge through shared experiences. In this study, multimedia was integrated with interactive teaching strategies fostering peer discussion, hands-on experimentation, and collaborative problem-solving. By creating a supportive, socially rich learning context, the study addresses passive learning and low motivation, exploring effective multimedia strategies that reinforce social engagement and active participation. Banihashem et al. [9] found that lessons designed on constructivist principles supported students' active participation and engagement in knowledge construction.

Figure 1 presents the conceptual framework. Multimedia-integrated physics instruction (MIPI) – incorporating simulations, videos, and animations – influences students' attitudes towards MIPI and physics learning, which in turn shapes their engagement across cognitive, emotional, and behavioural dimensions. This mediated relationship positions attitudes as a proximal mechanism linking MIPI to engagement outcomes.

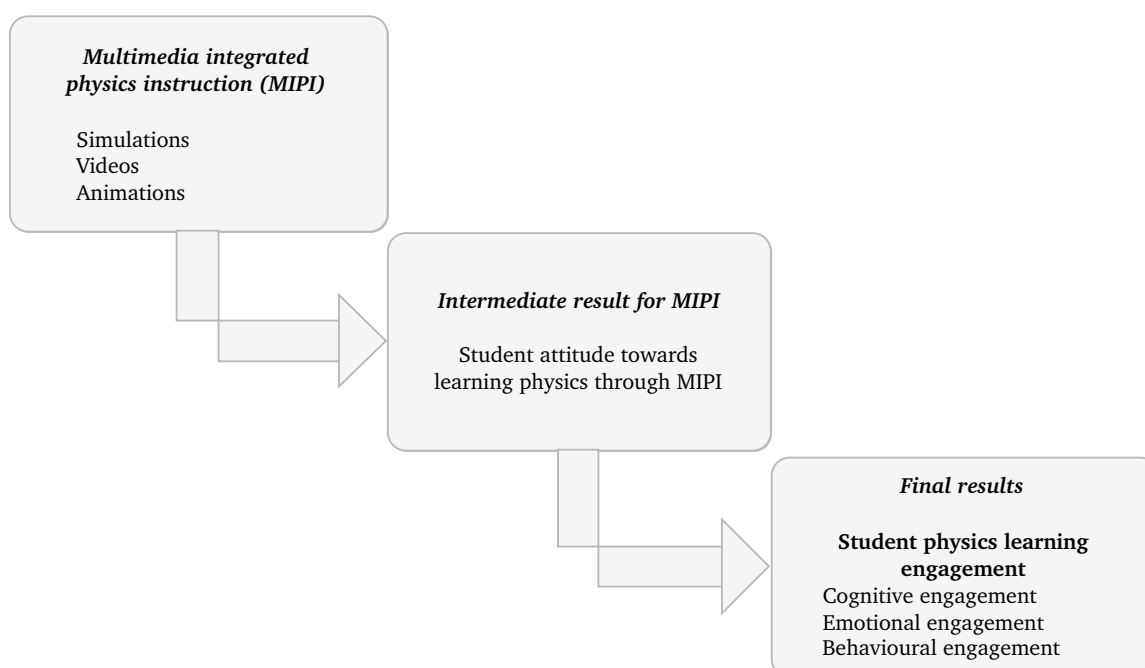


Figure 1: The impact of multimedia-integrated physics instruction (MIPI) on student attitude and learning engagement.

3. Methods

This study employed a convergent mixed-methods case study design [13], collecting quantitative and qualitative data concurrently in four government secondary schools in Mbeya Region, Tanzania.

The study involved two physics teachers and 96 Form Two students from the selected institutions. Form Two students were purposively selected because they had completed one year of secondary physics education, providing baseline familiarity with the subject while their attitudes and engagement patterns remained malleable. Most students (87.33%) were aged 14–16; 59.5% were female and 40.5% male. Informants were selected using purposive sampling, a non-probability technique suitable for mixed-methods research, chosen for their knowledge, roles, and direct involvement in multimedia integration in physics education [32].

Data collection methods included semi-structured interviews, focus group discussions, classroom observations, document reviews, questionnaires, pre-tests, post-tests, and classroom assignments. Interviews and focus groups with physics teachers, heads of schools, and students provided qualitative

insights into perceptions, experiences, and challenges with multimedia integration. Classroom observations contextualised these responses, offering deeper understanding of instructional practices. Document reviews, including schemes of work and lesson plans, supplemented qualitative data, while questionnaires, pre-tests, post-tests, and assignments provided quantitative data on attitudes and performance.

Focus groups with students triangulated the results. A pre-intervention questionnaire established baseline data. All students were taught identically (same lesson plan) by teachers with equal experience (four years) and qualifications (bachelor's degree). The intervention topic was Sustainable Energy Sources, taught through videos and animations covering wind energy, solar energy, water energy, geothermal energy, and sea wave energy. These energy systems involve spatially dynamic, component-based processes difficult to convey through text or static diagrams alone, requiring learners to understand energy transformation. Such causal and mechanical relationships are ideally taught through narrated animations that simultaneously present verbal explanations and visual representations, per CTML principles [11, 30]. Multimedia materials comprised open-access PhET Interactive Simulations (University of Colorado Boulder), PowerPoint, and video editing software aligned with the Tanzanian national syllabus.

Qualitative data from interviews, focus groups, observations, and document reviews were transcribed and thematically analysed using MAXQDA 24, following Creswell and Creswell [13] and Cohen, Manion and Morrison [12]. Open coding identified patterns related to increased interest, engagement, and motivation, organised into themes reflecting the significant positive shift in attitudes. Quantitative data from questionnaires, pre-tests, and post-tests were analysed using SPSS Version 23, with descriptive statistics (means, standard deviations, percentages) revealing enhanced engagement and understanding. Paired and independent *t*-tests confirmed statistically significant improvements.

Validity, reliability, and trustworthiness were ensured through rigorous methods. Instruments, including questionnaires and tests, were reviewed by physics education experts from the University of Dodoma. A pilot study refined these tools. The Cronbach's alpha reliability for the Likert scale measuring students' attitudes towards physics learning through multimedia-integrated instruction was determined through the pilot study and standardised to 0.72. Triangulation of data from students, teachers, and heads of schools, combined with member checking and inter-coder reliability, enhanced credibility [20, 29]. Dependability was achieved through diverse school sampling and research assistant involvement, with SPSS verifying data consistency [29]. Confirmability was ensured via peer reviews, and transferability was supported by detailed accounts of student and teacher experiences [13].

4. Results

4.1. Effect of multimedia-integrated physics instruction (MIPI) on students' attitudes towards physics learning

The analysis of students' attitudes towards physics before multimedia integration (table 1) reveals that most responses fell within the neutral range on a 5-point scale (1.0–1.4 = strongly disagree (SD), 1.5–2.4 = disagree (D), 2.5–3.4 = neutral (N), 3.5–4.4 = agree (A), 4.5–5.0 = strongly agree (SA)). The overall mean score of 2.89 indicates a neutral stance towards learning physics.

After multimedia integration (table 2), responses shifted to the “strongly agree” range, with an overall mean of 4.86, indicating a highly favourable attitude towards physics.

Table 3 confirms a highly significant difference (paired $t = 41.18$, $df = 95$, $p < .001$). The mean difference of 1.97, with a post-intervention mean of 4.86, indicates substantial improvement in students' perception of physics.

Table 1

Students' attitudes towards physics learning through multimedia-integrated physics instruction before intervention.

Statement	SD F (%)	D F (%)	N F (%)	A F (%)	SA F (%)	M
Learning through videos and animations makes complex physics concepts easier to understand.	0(0)	4(4)	21(21.2)	50(50.5)	24(24.2)	3.95
I can retain physics information better when taught using videos and animations.	1(1)	5(5.1)	31(31.3)	48(48.5)	14(14.1)	3.7
The use of videos and animations in physics lessons helps clarify topics I find difficult.	6(6.1)	27(27.3)	40(40.4)	21(21.2)	5(5.1)	2.92
I am more engaged in physics lessons that incorporate videos and animations.	10(10.1)	19(19.2)	35(35.4)	28(28.3)	7(7.1)	3.03
Videos and animations used in physics class increases my motivation to learn the subject.	30(30.3)	32(32.3)	25(25.3)	10(10.1)	2(2)	2.21
I am more likely to attend and pay attention in physics classes that use videos and animations as teaching tools.	18(18.2)	22(22.2)	27(27.3)	24(24.2)	8(8.1)	2.82
My interest in physics has increased due to the use of videos and animations in teaching.	4(4)	11(11.1)	28(28.3)	22(22.2)	34(34.3)	3.72
I like learning physics topics which are taught through videos and animations.	3(3)	19(19.2)	38(38.4)	34(34.3)	5(5.1)	3.19
I feel more competent in physics after learning through videos and animations.	5(5.1)	22(22.2)	43(43.4)	24(24.2)	5(5.1)	3.02
I prefer physics lessons that include a variety of multimedia elements over traditional lectures.	30(30.3)	21(21.2)	22(22.2)	20(20.2)	6(6.1)	2.51
Videos and animations make physics learning more relevant to real-world applications.	1(1)	8(8.1)	50(50.5)	35(35.4)	5(5.1)	3.35
I believe that the use of videos and animations should be a standard approach in teaching physics.	7(7.1)	25(25.3)	34(34.3)	30(30.3)	3(3)	2.97
Videos and animations in physics helps me understand complex concepts better.	14(14.1)	27(27.3)	28(28.3)	27(27.3)	3(3)	2.78
Using videos and animations in physics makes me more motivated to learn.	35(35.4)	29(29.3)	22(22.2)	12(12.1)	1(1)	2.14
I enjoy participating in discussions and activities related to physics when videos and animations are used.	33(33.3)	23(23.2)	34(34.3)	9(9.1)	0(0)	2.19
The use of videos and animations in physics improves my problem-solving skills.	7(7.1)	19(19.1)	39(39.4)	31(31.3)	3(3)	3.04
I feel more connected to real-life applications of physics when videos and animations are used in teaching physics.	2(2)	19(19.2)	41(41.4)	31(31.3)	6(6.1)	3.2
I feel more encouraged to ask questions and seek clarification in physics lessons with videos and animations.	6(6.1)	16(16.2)	31(31.3)	35(35.4)	11(11.1)	3.29
Using videos and animations in physics increases my curiosity and desire to explore the subject further.	32(32.3)	25(25.3)	27(27.3)	12(12.1)	3(3)	2.28
The use of videos and animations help me visualize abstract physics concepts.	28(28.3)	33(33.3)	27(27.3)	10(10.1)	1(1)	2.22
Using videos and animations in physics learning improves my ability to connect different physics topics together.	14(14.1)	27(27.3)	28(28.3)	27(27.3)	3(3)	2.78
The use of videos and animations in physics class make me more attracted to learn physics.	30(30.3)	32(32.3)	25(25.3)	10(10.1)	2(2)	2.21
Average						2.89

Table 2

Students' attitudes towards physics learning through multimedia-integrated physics instruction after intervention.

Statement	SD F (%)	D F (%)	N F (%)	SA F (%)	A F (%)	M
Learning through videos and animations makes complex physics concepts easier to understand.	0(0)	0(0)	0(0)	10(10.4)	86(89.6)	4.9
I can retain physics information better when taught using videos and animations.	0(0)	0(0)	0(0)	25(26)	71(74)	4.74
The use of videos and animations in physics lessons helps clarify topics I find difficult.	0(0)	0(0)	2(2.1)	13(13.5)	81(84.4)	4.82
I am more engaged in physics lessons that incorporate videos and animations.	0(0)	0(0)	1(1)	16(16.7)	79(82.3)	4.81
Videos and animations used in physics class increases my motivation to learn the subject.	0(0)	0(0)	0(0)	6(6.3)	90(93.8)	4.94
I am more likely to attend and pay attention in physics classes that use videos and animations as teaching tools.	0(0)	0(0)	0(0)	6(6.3)	90(93.3)	4.94
My interest in physics has increased due to the use of videos and animations in teaching.	1(1)	0(0)	0(0)	13(13.5)	82(85.4)	4.82
I like learning physics topics which are taught through videos and animations.	0(0)	0(0)	1(1)	9(9.4)	86(89.6)	4.89
I feel more competent in physics after learning through videos and animations.	0(0)	0(0)	0(0)	9(9.4)	87(90.6)	4.91
I prefer physics lessons that include a variety of multimedia elements over traditional lectures.	0(0)	0(0)	0(0)	14(14.6)	82(85.4)	4.85
Videos and animations make physics learning more relevant to real-world applications.	0(0)	0(0)	0(0)	8(8.3)	88(91.7)	4.92
I believe that the use of videos and animations should be a standard approach in teaching physics.	0(0)	1(1)	1(1)	7(7.3)	87(90.6)	4.88
Videos and animations in physics helps me understand complex concepts better.	0(0)	0(0)	0(0)	8(8.3)	88(91.7)	4.92
Using videos and animations in physics makes me more motivated to learn.	0(0)	0(0)	1(1)	10(10.4)	85(88.5)	4.88
I enjoy participating in discussions and activities related to physics when videos and animations are used.	0(0)	0(0)	0(0)	11(11.5)	85(88.5)	4.89
The use of videos and animations in physics improves my problem-solving skills.	0(0)	1(1)	1(1)	21(21.9)	73(76)	4.73
I feel more connected to real-life applications of physics when videos and animations are used in teaching physics.	0(0)	0(0)	0(0)	16(16.7)	80(83.3)	4.83
I feel more encouraged to ask questions and seek clarification in physics lessons with videos and animations.	0(0)	0(0)	1(1)	15(15.6)	80(83.3)	4.82
Using videos and animations in physics increases my curiosity and desire to explore the subject further.	0(0)	0(0)	0(0)	11(11.5)	85(88.5)	4.89
The use of videos and animations help me visualize abstract physics concepts.	0(0)	0(0)	1(1)	15(15.6)	80(83.3)	4.82
Using videos and animations in physics learning improves my ability to connect different physics topics together.	0(0)	0(0)	1(1)	14(14.6)	81(84.4)	4.83
The use of videos and animations in physics class make me more attracted to learn physics.	0(0)	0(0)	1(1)	9(9.4)	86(89.6)	4.89
Average						4.86

4.2. Impact of multimedia-integrated physics instruction on students' learning engagement

The study identified seven themes: enhanced interest and enjoyment; engagement with physics concepts; increased motivation to attend classes; perceived usefulness of physics in real-world contexts; increased confidence in learning physics; shift in career interest related to physics; and impact on engagement and participation.

Table 3

Paired sample *t*-test results on students' attitude towards physics learning through multimedia-integrated instruction.

		Mean	Standard deviation	<i>t</i>	df	Sig. (2-tailed)
Pair 1	Post_Average – Pre_Average	1.97159	0.46906	41.183	95	0.000

4.2.1. Enhanced interest and enjoyment in physics

Multimedia integration significantly increased students' interest and enjoyment. Pre-intervention, students held a neutral stance ($M = 2.89$); post-intervention, this rose to 4.86.

Qualitative data support this finding. One student stated:

Watching audiovisual materials, such as videos, enhances my enjoyment of the subject and increases my motivation to learn physics. The engaging visual presentations make complex concepts easier to understand, and I feel more eager to explore new topics if videos continue to be used in lessons. (Student 4, School C, September 2024)

Teachers also observed heightened interest, with one remarking:

When teaching is conducted using a projector, students become highly engaged and show a greater interest in the lesson. The visual and interactive aspects capture their attention, making them more eager to participate, follow instructions, and understand the subject matter effectively. (Physics teacher, School A, August 2024)

Additionally, students who were previously disengaged showed curiosity, as a teacher noted:

Students whom I previously believed to be uninterested in the subject have shown increased curiosity and enthusiasm when multimedia tools are used. They now actively engage with the content, eager to observe, explore, and understand what is being presented. (Physics teacher, School D, August 2024)

These findings suggest that, according to students' perceptions, multimedia plays a key role in making physics lessons more appealing and enjoyable.

The findings demonstrate that multimedia integration significantly boosted students' interest and enjoyment in physics, with the mean score rising from 2.89 (neutral) to 4.86 (strongly agree) post-intervention. Qualitative data, including student and teacher feedback, highlight how videos and animations transformed physics into an engaging and enjoyable subject, particularly for previously disengaged students. This aligns with Hasas et al. [21], who emphasise that ICT integration enhances student enjoyment by making abstract physics concepts visually appealing and interactive. Similarly, Liliana et al. [28] found that online interactive multimedia increased student interest in physics, corroborating the study's qualitative reports of enthusiasm. Tembrevilla and Milner-Bolotin [41] further support this, noting that science demonstration videos foster excitement, aligning with teachers' observations of heightened student curiosity when multimedia is used.

From an international perspective, UNESCO's framework on ICT in education emphasises the role of digital tools in fostering inclusive and engaging learning environments, which supports the study's findings on increased enjoyment [45]. The World Bank's Education 2030 agenda highlights the importance of innovative pedagogies to enhance student motivation, aligning with the study's evidence of multimedia sparking interest [55]. However, Al-Kamzari and Alias [4] suggest a potential contradiction, noting that game-based multimedia may yield varying engagement levels depending on format, which could imply that not all multimedia types are equally effective. Despite this, the UN's Sustainable Development Goal 4 (SDG 4) on quality education underscores the need for engaging teaching methods, reinforcing the study's claim that multimedia significantly enhances interest and enjoyment in physics education.

4.2.2. Engagement with physics concepts

Multimedia tools have greatly enhanced students' engagement with physics concepts by improving their understanding and visualisation of abstract topics. Quantitative results indicate that the statement: "Learning through videos and animations makes complex physics concepts easier to understand" received a pre-integration mean of 3.95, which increased to 4.9 after multimedia implementation.

Students shared how videos clarified complex topics and helped them relate classroom content to real-world scenarios. For example, one student mentioned,

Before watching the animation, I found it difficult to understand the differences between tidal energy and wave energy. However, after watching the video, I gained a clear understanding of how they work and why do they differ. (Student 1, School C, September 2024)

Another student added,

After watching the video, I learned the step-by-step process of making a solar cooker, which provided me with valuable insights. The demonstration was so clear and inspiring that it encouraged me to take the initiative and build one myself. (Student 5, School C, September 2024).

Teachers also reported increased engagement, stating that students actively participated in lessons and were excited to connect concepts to practical applications.

The study reports that multimedia tools improved students' engagement with physics concepts, with the mean score for understanding complex concepts increasing from 3.95 to 4.9 post-multimedia integration. Students noted that videos clarified abstract topics like tidal and wave energy, enhancing comprehension and practical application. This is supported by Banda and Nzabahimana [7], who found that PhET simulations significantly improved conceptual understanding by visualizing abstract physics topics. Nyirahabimana et al. [34] also confirm that multimedia in quantum physics classes enhances engagement through interactive visualisations, aligning with the study's findings on students building solar cookers after video demonstrations.

4.2.3. Increased motivation to attend classes

Multimedia integration significantly increased motivation to attend physics classes. Pre-intervention motivation was low ($M = 2.21$); post-intervention, it rose to 4.94.

Students expressed how multimedia made physics less intimidating:

I always believed that physics was a difficult subject, and I often struggled to understand its concepts. However, watching these videos simplified complex parts, making them easier to grasp and more interesting. This newfound clarity has inspired me to keep studying physics. (Student 3, School D, September 2024)

Teachers observed improved classroom dynamics, with students more attentive and eager to explore topics. This is corroborated by Banda and Nzabahimana [8], who found PhET simulations boosted motivation among Malawian physics students. Rogti [37] note mobile-based multimedia enhances thinking engagement.

The UN's SDG 4 emphasises inclusive education motivating participation [48]. Al-Kamzari and Alias [4] caution multimedia's impact may be less effective for students with low prior interest. The World Bank's push for digital learning to reduce dropout rates supports increased attendance [55]. Wagino et al. [52] and Gumisirizah, Nzabahimana and Muwonge [18] confirm e-learning innovations and YouTube videos enhance motivation.

4.2.4. Perceived usefulness of physics in real-world contexts

Multimedia significantly improved students' perception of physics' real-world relevance. Pre-intervention mean was 3.35; post-intervention, 4.92.

Students connected physics to daily life:

I am eager to educate my family about the benefits of using renewable energy sources, such as solar panels. They are environmentally friendly, help reduce carbon emissions, and, although the initial cost may be high, they prove cost-effective over time. (Student 5, School D, September 2024)

Another shared:

Watching the video on hydroelectric power, especially the function of water pressure, gave me ideas to solve a plumbing issue at home. I realised our water pipe was too wide and clogged with sand, so we replaced it with a smaller one, improving the pressure. (Student 7, School D, September 2024)

Teachers confirmed multimedia helped bridge theoretical knowledge with practical applications, even with limited laboratory resources. Gerhátová, Perichta and Palcut [16] found multimedia in project-based learning enhanced perceived relevance of physics topics. Crogman et al. [14] confirm virtual and augmented reality help apply physics to real-life scenarios.

UNESCO's emphasis on contextual learning through technology supports these findings [47]. Salame and Makki [38] note PhET simulations may have limited real-world impact without hands-on components. The World Bank's STEM focus aligns with multimedia fostering practical applications [22]. Gerhátová, Perichta and Palcut [16] and Abdulrahman et al. [1] highlight multimedia's role in bridging theory and practice.

4.2.5. Increased confidence in learning physics

Multimedia integration significantly boosted students' confidence. Pre-intervention confidence was moderate ($M = 3.02$); post-intervention, it rose to 4.91.

Students reported feeling more capable of explaining concepts:

After watching the video, I gained a clear understanding of how a solar cooker works, something that previously confused me. I now feel confident enough to explain the process to my peers and help them understand it as well. (Student 2, School D, September 2024)

Another added:

Watching multimedia really helped me get things in a more real way, and now I can explain them to others without any trouble. It made everything easier to understand and way clearer than before. (Student 5, School D, September 2024)

Teachers noted students were more willing to ask questions and participate, fostering an interactive environment. Werth, West and Lewandowski [54] corroborate this, finding multimedia in remote physics courses increased confidence. Uden et al. [44] note STEM project-based learning with multimedia enhances self-efficacy.

The UN's SDG 4 prioritises building learner confidence through innovative teaching [48]. Pellas [36] caution AI-generated multimedia may overwhelm some students. UNESCO's learner-centred digital pedagogies align with increased participation [17]. Jiménez-Valverde et al. [23] and Torres, Pulukuri and Abrams [43] confirm gamified multimedia enhance confidence by making concepts accessible.

4.2.6. Shift in career interest related to physics

Multimedia integration sparked interest in physics-related careers. Pre-intervention mean was 2.51; post-intervention, 4.85.

Students expressed newfound interest:

Watching these videos got me really interested in physics and made me want to learn even more. They helped me see how fun and exciting physics can be, and now I'm thinking about studying it more in the future. (Student 6, School D, September 2024)

Another commented:

From the first time I started physics in Form One, I loved it. But when I got to Form Two and we started learning about current electricity, I didn't understand it at all. I even thought of dropping physics in Form Three, but the animations and videos encouraged me, and now I plan to continue studying it. (Student 7, School D, September 2024)

This aligns with Alam and Mohanty [5], who found robotics-integrated education sparked STEM career interest. Tene et al. [42] note immersive technologies increase STEM enthusiasm. The World Bank's STEM emphasis supports multimedia fostering career interest [55]. Lai and Cheong [26] caution accessibility barriers may limit impact. UNESCO's STEM focus aligns with multimedia making physics relatable [46]. Beltozar-Clemente [10] note gamified multimedia enhances long-term engagement.

4.2.7. Impact on engagement and participation

Multimedia significantly improved engagement and participation. Pre-intervention engagement was moderate ($M = 3.03$); post-intervention, it rose to 4.81.

Students became more involved in group discussions and hands-on activities. A teacher noted:

With the integration of multimedia, students become active participants in their learning process. They are not just passive recipients of information, but are genuinely excited to explore and connect various concepts on their own, fostering deeper engagement and understanding. (Physics teacher, School C, August 2024)

Another mentioned:

As students move closer to the screen, their curiosity and eagerness to follow the content increase. This physical engagement enhances their focus, making them more attentive to the material being presented, which ultimately boosts their participation and overall learning experience. (Physics teacher, School D, August 2024)

Haetami et al. [19] confirm PhET simulations enhance participation. Anggraeni et al. [6] note digital multimedia fosters interactive environments. UNESCO's ICT Competency Framework emphasises technology's role in active learning [47]. Niță and Guțu [33] suggest engagement depends on institutional support. The World Bank's focus on interactive pedagogies aligns with increased participation [22]. Lampropoulos and Kinshuk [27] and Suhail, Bahroun and Ahmed [39] confirm virtual and augmented reality enhance engagement.

This is consistent with Abdulrahman et al. [1], who found multimedia tools significantly improve learning outcomes and attitudes in physics. Banda and Nzabahimana [8] report statistically significant improvements in motivation and achievement. UNESCO's Global Education Monitoring Report highlights technology's transformative role [17]. The World Bank's data-driven approach aligns with this study's rigour [55]. Werth, West and Lewandowski [54] report measurable improvements in student affect.

5. Conclusion and recommendations

This study provides the first mixed-methods evidence from Tanzania that CTML-aligned multimedia integration shifts student attitudes from neutral ($M = 2.89$) to strongly positive ($M = 4.86$) and enhances engagement across cognitive, emotional, and behavioural dimensions.

Findings confirm that multimedia serves as a mediating artefact in Vygotsky's sense, enabling social construction of physics knowledge in resource-constrained settings. The attitude-engagement mediation pathway warrants further testing.

For policy and practice, the Ministry of Education, Science and Technology (MoEST) should prioritise multimedia infrastructure (projectors, internet) and teacher professional development for CTML-aligned lesson design. Curriculum guidelines should embed multimedia components for STEM subjects.

Limitations include the four-week intervention risking novelty effects, four schools in one district limiting generalisability, and no direct achievement measure.

Future research should pursue experimental designs linking engagement to achievement; longitudinal studies across diverse physics topics; gender-differentiated effects; and teacher TPACK development for sustainable integration.

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