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Evaluating video-based PBL approach on performance and critical thinking ability among Ugandan form-2 secondary school students

Gumisirizah Nicholus^a , Joseph Nzabahimana^{a,b} and Charles M. Muwonge^c

^aAfrican Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda, College of Education, (UR-CE), Kayonza, Rwanda; ^bDepartment of Mathematics, Science and Physical Education, University of Rwanda, College of Education, (UR-CE), Kayonza, Rwanda; ^cDepartment of Educational Foundations and Psychology, Mbarara University of Science and Technology, Mbarara, Uganda

ABSTRACT

In recent years, there has been a growing emphasis on innovative teaching methods in secondary education as educators seek to enhance students' critical thinking abilities and motivation to learn. This research focuses on evaluating the impact of a video-based Problem-Based Learning (PBL) approach on the performance and critical thinking ability of Ugandan Form-2 secondary school students. We assessed students' performance and motivation for critical thinking using a test and their motivation using a motivational scale. The quasi-experimental design involved 144 students selected from four schools in the Sheema District. All students were pretested before the experimental group underwent a video-based PBL intervention and posttested after the intervention. Data entry and analysis were conducted using MS Excel 2016 and SPSS v.25. Inferential statistics revealed a statistically significant difference in critical thinking ability before and after learning the unit on simple machines in physics. Additionally, a positive motivation to learn physics was statistically proven after the intervention. Notably, students from government schools exhibited diverse performance, while private school students showed greater improvement and motivation after the instructional intervention. In conclusion, the results demonstrate that video-based PBL is an effective method for teaching physics and fostering motivation to learn the subject. Consequently, we recommend that teachers incorporate this approach into their daily teaching practices and call upon stakeholders to support the implementation of these resources in the classroom.

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Introduction

Problem-Based Learning (PBL) is an innovative and student-centered educational approach that has gained widespread recognition and application in various educational settings worldwide. PBL departs from traditional lecture-based teaching methods by placing students at the center of the learning process (Savery & Duffy, 2001). It engages learners in solving real-world problems (Vidic, 2011), promoting critical thinking (Suastra et al., 2019), collaboration (Silver-Hmelo, 2004), and active learning (Kanyesigye et al., 2023a). The roots of PBL can be traced back to medical education (Thistlethwaite et al., 2012), where it was first developed at McMaster University in the 1960s (Barrows & Tamblyn, 1980). Since then, PBL has been adapted and adopted in diverse disciplines, including science (Parno & Ni'mah, 2019), engineering (Seltpuk & Tarak, 2017), business (Stinson & Milner, 1996), and the humanities (Masek & Yamin, 2011). PBL parting from McMaster is highly tutor based with short learning circles, bigger tutor-led groups, and less open-ended problems than the PBL practiced at universities like Aalborg University

CONTACT Nicholus Gumisirizah  nichorusgumisirizah@gmail.com  African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda, College of Education, (UR-CE), Kayonza, Rwanda

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in Denmark or the CDIO (Conceive, Design, Implement, and Operate) approaches at KTH Stockholm or DTU in Denmark (Kolmos & De Graaff, 2015).

Several key principles, such as problem-centered learning, student-centered approach, collaboration, facilitator role, and interdisciplinary learning, characterize PBL (Schmidt et al., 2011). PBL begins with presenting an authentic, open-ended problem or scenario (Gumisirizah et al., 2024a). Students are tasked with understanding the problem, identifying relevant information, and proposing solutions (Gumisirizah et al., 2024b). This process encourages active exploration and inquiry (Yeo et al., 2012). In PBL, students take on the role of active learners and problem solvers. They work in small groups to research and discuss the problem, fostering self-directed learning (Gumisirizah et al., 2024b) and critical thinking (Yuberti et al., 2019). Collaboration is a fundamental aspect of PBL. Students work together, pooling their knowledge and skills to address complex problems (Gumisirizah et al., 2024b). This promotes teamwork, communication, and interpersonal skills. Instructors in PBL serve as facilitators or guides rather than traditional lecturers. They support students' learning by providing guidance, feedback, and resources when needed (So & Kim, 2009). PBL encourages interdisciplinary learning, as complex problems frequently require knowledge from multiple fields (Awang & Ramly, 2008). This promotes a holistic understanding of issues.

PBL offers several advantages in educational contexts, such as enhanced critical thinking, improved motivation, long-term knowledge retention, communication skills, and preparation for real-world challenges (Aidoo et al., 2016; Allen & Tanner, 2005; Schmidt et al., 2011; Shahreez et al., 2021; Srinivasan et al., 2007; Wilder, 2015). PBL fosters critical thinking skills as students analyze, evaluate, and synthesize information to solve problems (Susbiyanto et al., 2019). Students tend to be more motivated when they are actively engaged in solving real-world problems (Vidic, 2011), seeing the relevance of their learning. PBL promotes deeper understanding and retention of knowledge because students are actively constructing their knowledge (Osman & Kriek, 2021). Collaboration and group discussions in PBL enhance students' communication and interpersonal skills (Davidson & Major, 2014). PBL equips students with problem-solving abilities and adaptability (Gumisirizah et al., 2024b), essential in professional and personal life. However, while PBL offers many benefits, it is not without challenges. These may include the need for extensive planning, time constraints, and potential resistance from students accustomed to traditional teaching methods (Alt & Raichel, 2022; Khan et al., 2010; Macho-Stadler & Jesús Elejalde-García, 2013). Effective facilitation (Kanyesigye et al., 2022c) is critical to ensure that PBL experiences are successful.

While our exploration of the literature revealed limited existing research specifically focused on "Video-based Problem-Based Learning" as a distinct topic to improve student performance and motivation to learn physics, we acknowledge the significance of related studies. Notably, Williams (2022) has contributed valuable research on Problem-Based Learning (PBL) in physics education, as highlighted in [cite the specific source]. Despite the availability of literature on PBL in physics education, our investigation specifically targets the intersection of video-based learning and problem-based approaches, aiming to contribute novel insights into the potential enhancements in student performance and motivation within this unique context. This article, therefore, seeks to address the existing gap in the literature by exploring the specific dynamics of 'Video-based Problem-Based Learning' in physics education." Video-based education, a dynamic and evolving field, involves using video content as a potent tool in teaching and learning across various educational settings (Uwamahoro et al., 2021). Research in this domain explores the manifold benefits of video-based learning, ranging from heightened engagement and improved retention to its versatile applications in blended and flipped classroom models and in massive open online courses (MOOCs) (Guo et al., 2014). Studies delve into the intricacies of effective video production and design (Ndiokubwayo et al., 2020), emphasizing the importance of accessibility and inclusivity through features like closed captioning. Furthermore, video analytics and learning analytics are harnessed to monitor student engagement and evaluate instructional effectiveness (Mayer, 2014). Despite its advantages, video-based education also grapples with challenges such as technical issues and disparities in access. As the field evolves, emerging trends like virtual reality (VR) and augmented reality (AR) applications (Daineko et al., 2020) promise to shape the future landscape of video-based education further.

Literature review

Critical thinking, a foundational skill in education and problem-solving (Gumisirizah et al., 2024b), encompasses the capacity to rigorously analyze, evaluate, and synthesize information and ideas, fostering thoughtful, logical, and systematic decision-making processes. The critical thinking literature spans diverse topics, including its application in education (Sulasih et al., 2017), the development and validation of assessment tools (Sumarni et al., 2018), cognitive processes and strategies (Lamb et al., 2014), cross-disciplinary applications (Gumisirizah, Muwonge, et al., 2023), the impact of technology on critical thinking (La et al., 2020), cultural and global perspectives (Gumisirizah et al., 2024a), and its intersections with ethics, psychology, and decision-making, collectively illuminating the multifaceted nature and profound importance of this skill in addressing complex issues across various domains. While commonsensical thinking is valuable in everyday situations, critical thinking is particularly important in academic, professional, and complex problem-solving contexts where a deeper analysis and evaluation of information are required. Critical thinking is a cognitive skill that involves analyzing, evaluating, and synthesizing information to make reasoned judgments or decisions (Uddin, 2021). It goes beyond simply accepting information at face value and involves a deeper level of understanding and interpretation. Critical thinkers question assumptions, consider different perspectives, and use evidence and reasoning to form well-informed conclusions. On the other hand, Commonsense thinking relies on conventional wisdom, general beliefs, and everyday knowledge that is widely accepted within a particular culture or community (Davis & Sumara, 2014). It often involves relying on intuitive or familiar ways of understanding the world without rigorously evaluating evidence or alternative viewpoints. Therefore, acquiring critical thinking skills is crucial among the Higher Order Thinking Skills for the younger generation to confront the challenges of 21st-century education (Uddin, 2021).

While numerous past studies have assessed critical thinking, there appears to be a limited focus on measuring the motivation for critical thinking. For instance, the study by Sulasih et al. (2017) focused on assessing the critical thinking ability of high school students in learning static fluids. Using a descriptive method and instruments, the research revealed that students have high critical thinking skills overall, though there was a variation in specific abilities, with strengths in providing simple and advanced explanations and building basic skills. Tania et al. (2020) aimed to enhance students' critical thinking skills and ICT literacy in physics by utilizing e-handouts assisted by the PBL model. The findings indicate improvements in students' critical thinking skills and demonstrate a satisfactory impact on their ICT literacy. Likewise, research aimed to assess the impact of implementing a PBL model on students' physics achievement and critical thinking in Indonesian state senior high schools suggested that incorporating PBL enhances students' outcomes, providing valuable insights for teachers to diversify their teaching approaches (Mundilarto & Ismoyo, 2017). According to the theory of constructivist learning, the implementation of the PBL model focuses on individual activities and actions (Tarigan, 2017). Applying PBL in Physics learning targets four fundamental components of critical thinking: basic skills, knowledge base, willingness to ask questions, and self-reflection (Tarigan, 2017). The study's outcomes indicate that students experience an enhancement in critical thinking through implementing PBL in Physics education. Our present study measures the motivational aspects associated with critical thinking to provide a more comprehensive understanding of this cognitive process.

Motivation in learning physics is a complex and multifaceted topic encompassing various factors and theories. Understanding and nurturing motivation in learning physics is crucial for promoting student engagement and achievement in this challenging subject (Utha et al., 2023). Effective and engaging teaching methods and supportive and enthusiastic instructors can positively impact students' motivation in physics. Interactive lectures, hands-on experiments, and real-world applications can enhance interest and motivation (Kanyesigye et al., 2022c). Students are more motivated to learn physics when they perceive its relevance to their lives and future careers (Nyirahabimana et al., 2023). Physics educators should emphasize practical applications and connections to students' interests. Intrinsic and extrinsic motivation can also gear students' learning. Intrinsic motivation arises from internal factors such as curiosity and interest, while extrinsic motivation comes from external rewards or pressures (Dilber, 2012). A balance between intrinsic and extrinsic motivation is important, and educators should aim to nurture students' intrinsic interest in physics. Fair and constructive assessment methods and timely and meaningful

feedback can positively influence motivation (Ketonen et al., 2020). Students are more motivated when they see their progress and receive guidance on improvement. Collaboration with peers, group discussions, and peer teaching (Mbonyirivuze et al., 2021; Ndiokubwayo et al., 2021) can enhance motivation by fostering a sense of belonging and shared goals.

It is essential to incorporate practical implications and strategies that enhance student motivation and engagement to address the need for video-based problem-based learning (video-based PBL) in physics education. Moreover, video-based PBL can spotlight real-world applications of physics concepts, illustrating their relevance to everyday life and various careers (Susbiyanto et al., 2019), thus motivating students through tangible connections. By offering learners choices and autonomy within the video-based PBL framework, educators empower them to take ownership of their learning journey, fostering intrinsic motivation. Clear learning objectives, expectations, and timely feedback provided through video resources help students gauge their progress and keep them engaged (Ndiokubwayo et al., 2020). In this positive and inclusive online learning environment, questions, curiosity, and experimentation are encouraged, ensuring students grasp complex physics concepts and develop a lasting enthusiasm for the subject.

In this study, we have adopted the Self-Determination Theory (SDT) as our theoretical framework. SDT posits that motivation is underpinned by three fundamental psychological needs (Gagné & Deci, 2005; Smith & Doe, 2020): autonomy, which reflects an individual's desire to exercise control over their actions; competence, which represents the need to feel capable and effective in one's endeavors; and relatedness, which encompasses the longing for social connection and a sense of belonging. In the specific context of physics education, our approach aligns with the principles of SDT by emphasizing the importance of creating pedagogical environments that afford students opportunities for autonomy in their learning journey by nurturing their sense of competence through effective teaching practices and fostering a vibrant sense of belonging within the physics community.

In the PBL process (Gumisirizah, Nzabahimana, et al., 2023; Kanyesigye et al., 2022a), the first step involves the presentation of a real-world problem to the students, sparking their interest and curiosity. Students begin their learning journey with problems, highlighting a self-directed learning approach within collaborative teams (Kolmos & De Graaff, 2015). Once the problem is introduced, the second step focuses on organizing ideas and brainstorming potential solutions within the group. The collaborative effort continues in the third step, where students engage in group work to delve into the complexities of the problem, fostering teamwork and critical thinking. Following the group exploration, the fourth step entails the presentation of findings, where each group shares its proposed solutions, discoveries, and insights with the rest of the class. Lastly, in the fifth step, students engage in the process of generalization, extracting broader principles or lessons learned from the specific problem-solving experience, promoting a deeper understanding of the subject matter and its real-world applications.

In alignment with its 2016–2021 'Knowledge for the world' strategy, Aalborg University focused on integrating Information Technology into PBL (Habbal et al., 2024). A center for digitally supported learning was established to aid in developing digital learning forms, particularly in PBL. Drawing inspiration from the flipped classroom model, researchers at Aalborg University conducted studies on various digital PBL environments as part of a broader investigation into PBL for the future. Subsequently, projects have been initiated, including one outlining general principles for digitalization in a PBL context. By integrating these elements, we aim to enhance student motivation and engagement in physics learning, ultimately contributing to their academic success and long-term interest in the subject matter. By applying motivational theories and implementing effective teaching strategies, educators can inspire students to explore the wonders of physics and excel in their studies.

Evaluating both private and public schools in terms of performance and motivation for critical thinking holds significant implications for various stakeholders, including educators, parents, policymakers, and the broader education system. Our previous study showed that students from government schools showed similar performance before and after instruction, while private school students demonstrated more significant improvement. Kanyesigye et al. (2023b) explored factors such as gender difference, age difference, subjects' combination, single-gender versus mixed schools, and government versus privately-owned schools. Despite the thorough examination, no statistically significant effects were identified. Therefore, such inconclusive results across various studies highlight the need for continued research and

exploration of this phenomenon by researchers. Ongoing studies are essential to deepen our understanding of the complexities involved in the relationship between these factors and the effectiveness of teaching methodologies.

This study aimed to evaluate the impact of a video-based PBL approach on the critical thinking ability of Form-2 secondary school students in Uganda. Specifically, it intended to the following research questions:

How does performance vary among students in the educational context, as measured by academic achievement test?

What is the level of motivation for critical thinking among students, as measured by a motivational scale?

How do public and private school students differ in performance and motivation?

Methodology

Research design

This research seeks to evaluate the effectiveness of a video-based Problem-Based Learning (PBL) strategy in enhancing the critical thinking abilities of secondary school students within Sheema District, located in Western Uganda. The study involved 144 students from a random selection of two public and two private schools, with teachers trained to employ the video-based PBL approach and equipped with the requisite knowledge and resources. The intervention itself revolved around implementing the video-based PBL method, with educators receiving guidance on incorporating PBL into their teaching practices, including sourcing and utilizing relevant YouTube videos on the subject of simple machines. The instructional phase spanned approximately three weeks to ensure comprehensive exposure to the PBL approach. To establish a baseline for critical thinking ability and motivation, all participating students underwent a pretest, comprising a physics achievement test and a critical thinking ability motivational scale. Subsequently, teachers introduced the video-based PBL approach, emphasizing the cultivation of critical thinking skills and motivation. The research culminated in a posttest, mirroring the pretest's components, to gauge the intervention's impact.

Teaching intervention delivered

Before undertaking teaching intervention, teachers received training in the implementation of PBL. Throughout the lesson delivery, they were provided support and supervision to ensure the correct application of PBL. The instructional approach involved five steps of PBL (teacher present the problem, students organize their ideas on the problem, students work in groups guided by teacher, each group presents its findings, teacher helps students generalize their findings) as stipulated in various studies (Gumisirizah, Nzabahimana, et al., 2023; Kanyesigye et al., 2022a). The groups were tasked with solving a problem related to simple machines through discussions. Specific roles were assigned within each group, including a group leader, secretary, timekeeper, and peacemaker. Throughout the activity, the groups engaged in discussions on tasks related to simple machines, working towards consensus on possible solutions for the presented problem. Subsequently, a group member presented their group's work, receiving feedback from other groups, facilitated by the teacher. This group work technique fostered in-depth learning, enhancing students' knowledge and skills such as teamwork, interpersonal communication, and peer teaching.

Alongside PBL, YouTube videos related to simple machine content were watched in class. The adherence to the watch guideline, as outlined by Ndiokubwayo et al. (2020), was meticulously followed. The teacher implemented a structured approach where the topic was introduced, and students were subsequently prepared to watch a video relevant to that particular concept. Before playing the video, the teacher engaged the students by prompting them to predict the anticipated outcome. For example, the teacher introduced the topic of inclined planes as a part of the lesson on simple machines. He decided to show a video demonstration of how an inclined plane works. Before playing the video, he asked the students to predict what would happen when a ball is rolled down an inclined plane. The students, in

response, made predictions such as the ball rolling faster or slower or changing direction. This approach aligns with the watch guideline and actively engages students in the learning process by encouraging them to think critically about the concept of inclined planes before witnessing the video demonstration.

In contrast, the control group followed traditional learning methods, where the teacher presented topics on the blackboard and explained them, and students followed along, asking questions as needed. Thus, they did not follow the five steps of PBL and did not watch YouTube videos.

Data collection tools

The authors designed the Physics Academic Achievement Test in simple machines to assess students' understanding of basic concepts related to simple machines, mechanical advantage, efficiency, and related physics principles. It consists of multiple-choice items that require students to apply their knowledge to solve problems. Here is a brief description of the test items: Efficiency of a Machine: This item assesses students' understanding of efficiency in a machine by presenting a scenario involving load, effort, distance, and work. Students are asked to calculate the machine's efficiency based on the given parameters. Block and Tackle System: This question challenges students to determine the velocity ratio of a block and tackle system with specific characteristics, such as the number of pulleys in the system. It tests their knowledge of mechanical advantage and velocity ratio. Expression of Efficiency: Students are required to identify the correct expression for calculating the efficiency of a machine. This item evaluates their grasp of the mathematical representation of efficiency in machines. Efficiency Calculation: This item presents a scenario where students need to calculate the efficiency of a machine based on the effort required and the velocity ratio. It tests their ability to apply the efficiency formula in practical situations. Energy Wasted in a Pulley System: This question involves a pulley system and requires students to calculate the amount of wasted energy. It assesses their understanding of energy conservation and work done in mechanical systems. Mechanical Advantage Calculation: Students are tasked with calculating a machine's Mechanical Advantage (MA) given the effort and load. This item tests their ability to apply the concept of MA in machine analysis. Pulley System Characteristics: This multiple-choice item presents statements about a pulley system's characteristics, including mechanical advantage, efficiency, and load variation. Students need to determine true statements based on their knowledge of pulley systems. Explanation of Machine Work: Students are asked to identify statements that explain how a machine performs work. This item assesses their understanding of the fundamental principles of machines, including load, effort, and distance. Second-Class Lever Characteristics: This item focuses on the characteristics of second-class levers. Students are required to identify the statements that accurately describe second-class lever systems. Velocity Ratio Formula: This question tests students' knowledge of the correct formula for calculating velocity ratio in machines. They need to select the formula representing the relationship between the distances the load and effort moved. The pilot phase of this test showed a .87 high split-half reliability coefficient.

The Critical Thinking Motivational Scale (Valenzuela et al., 2017) used in this study was designed to assess students' motivational attitudes toward critical thinking. It consists of five categories, each comprising a set of statements to which participants indicate their level of agreement or disagreement. Here is a breakdown of each category: Expectancy: This category explores students' beliefs about their ability to engage in critical thinking. Participants respond to statements about their confidence in their critical thinking skills, including their perception of being better than their peers in reasoning and their capacity to learn and apply rigorous thinking. Task Value (Attainment): This section assesses the importance students attach to developing critical thinking abilities. It includes statements that measure the value students place on learning how to reason correctly, being proficient in reasoning, using intellectual skills effectively, and solving problems adeptly. Utility: This category delves into the perceived utility of critical thinking. It evaluates students' views on how critical thinking contributes to their future professional development, its relevance in daily life, and its usefulness in other subjects and courses. Intrinsic/Interest: This section gauges students' intrinsic motivation and interest in critical thinking. It includes statements reflecting a positive disposition towards properly reasoning, thinking critically, and improving their thinking skills. It assesses how much students enjoy engaging in rigorous and critical thinking processes. Cost: The final category considers the willingness of students to invest time and effort in

developing critical thinking skills. It includes statements about the sacrifices students are willing to make, such as dedicating time that would otherwise be spent on other activities to enhance their reasoning abilities. The internal consistency (using Cronbach alpha) of this scale was found to be .793 (all 19 items) high reliability, .428 (expectancy) medium reliability, .411 (attainment), .686 (utility), .574 (interest), and .594 (cost) during our pilot phase.

Participants rate their agreement with each statement on a scale ranging from “Strongly Disagree (SD)” to “Strongly Agree (SA).” This scale provides a comprehensive overview of students’ motivations for critical thinking and their perceptions of its importance and utility in various aspects of their lives (Valenzuela et al., 2017). The responses help researchers assess the participants’ intrinsic motivation and willingness to invest effort in developing critical thinking abilities.

Data analysis

We recorded data in MS Excel 2018. We assigned one point for each correct answer to every question to score the performance test and then calculated the average total score as a percentage. We imported pre and posttest scores into SPSS 25 to compute inferential statistics. Since the performance scores were derived from a performance test, we used parametric tests to measure inferential differences. Consequently, we employed a paired samples t-test to assess the statistically significant difference between the pre and posttests. Additionally, we utilized repeated measures ANOVA to examine differences between public and private schools before and after learning.

For the survey test, we followed a similar procedure. However, we calculated the number of students who responded on a five-point scale and converted the percentages into motivational factors. Since the survey focused on motivational attitudes, we used nonparametric tests to compute inferential statistics. Specifically, we applied the Wilcoxon rank test to measure the difference before and after learning and the Kruskal-Wallis test to assess differences in school characteristics.

Ethical considerations

Ethical considerations in this research encompass obtaining informed consent from both students and their guardians, ensuring the protection of minors, maintaining strict data privacy and confidentiality, respecting local cultural sensitivities in Sheema District, and adhering to principles of beneficence and non-maleficence by minimizing potential harm and maximizing benefits for participants and society.

Findings

Table 1 shows the descriptive statistics from physics performance tests before and after learning simple machines with video-based PBL, broken down by school characteristics (public and private schools). Performance descriptive statistics. For instance, you can see that after the intervention, students in private schools had a notably higher average score on the posttest (67.71%) compared to their pretest score (34.71%), indicating a significant improvement. Conversely, students in public schools also improved but to a lesser extent, with their posttest score (50.41%) higher than their pretest score (38.38%).

In this table, “Time of Intervention” specifies whether it is the pretest (before learning) or posttest (after learning). “School Characteristics” distinguishes between public and private schools. “Mean”

Table 1. Descriptive statistics from performance test.

Time of intervention	School characteristics	Mean %	Std. Deviation %	N
Before learning (pretest)	Public school	38.38	17.52	74
	Private school	34.71	13.05	70
	Total	36.60	15.56	144
After learning (posttest)	Public school	50.41	16.67	74
	Private school	67.71	19.35	70
	Total	58.82	19.95	144

represents the average scores, “Std. Deviation” is the standard deviation, and “N” is the number of observations or participants in each category.

The analysis of variance results indicates a statistically significant difference ($p < .001$) after the learning intervention. This suggests that the video-based PBL approach significantly impacted critical thinking ability performance (See Table 2). The “ $p < .001$ ” indicates that the probability of obtaining such results by chance is extremely low, providing strong evidence of the intervention’s effectiveness. Similarly, a very high statistically significant ($p < .001$) difference between public and private schools with a .197 effect size was revealed in favor of private schools. The effect size of 0.197 indicates a small to moderate effect, suggesting that private schools, on average, demonstrated a somewhat larger improvement than public schools after the learning intervention. This difference, coupled with the highly significant p-value, indicates that the type of school (public vs. private) had a notable impact on the outcome being measured.

Table 3 presents descriptive statistics from a critical thinking motivational survey administered before and after learning simple machines with video-based PBL in public and private schools. The “Mean Rank %” column displays each category’s mean rank percentage of motivation scores. The mean rank percentage represents the average rank of motivation within each group. For example, before the learning intervention, students in public schools had an average rank percentage of 64.75%, while students in private schools had a higher average rank percentage of 80.69%. The “N” column shows the number of participants or observations in each category. In this case, there were 74 students in public schools and 70 in private schools for both the pretest and posttest, resulting in 144 participants for each time point. The table compares the mean rank percentages of motivation scores for students in public and private schools before and after the learning intervention. For instance, before and after the intervention, students in private schools had higher mean rank percentages, indicating higher levels of motivation, than students in public schools.

The Wilcoxon Signed Ranks Test showing a highly statistically significant difference after learning due to motivation suggests that the learning intervention, possibly the video-based PBL approach, substantially impacted students’ motivation levels. The “highly statistically significant” result (often denoted as $p < .001$) indicates that the observed differences in motivation are very unlikely to have occurred by chance, providing strong evidence that the intervention positively affected students’ motivation. Additionally, the Kruskal-Wallis Test revealing that private schools outperformed public schools significantly ($p < .01$) in motivation when learning simple machines implies that there are notable differences in motivation levels between students from public and private schools. The p-value of less than 0.01 indicates that this difference is highly unlikely to be due to random variation.

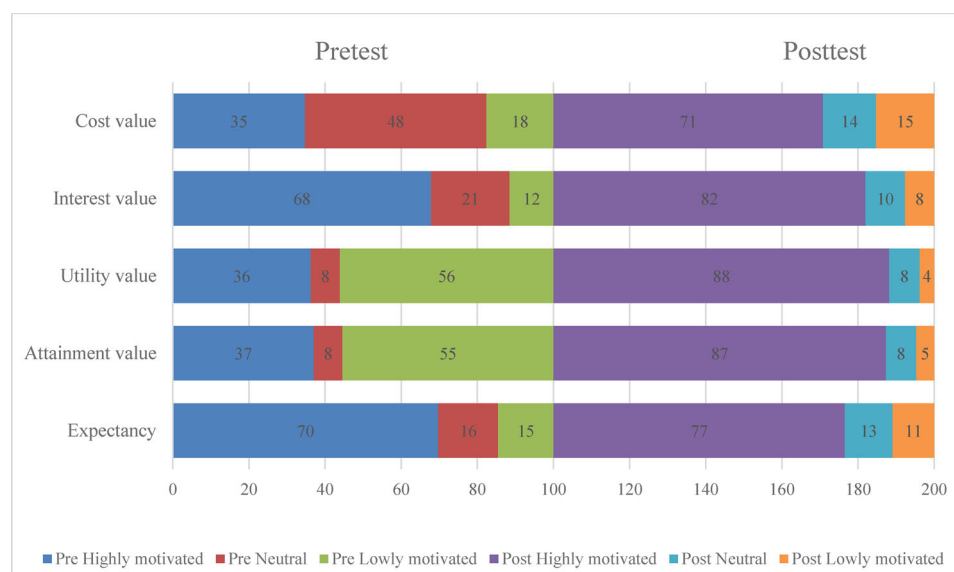
Figure 1 displays data related to the percentage of highly motivated students before and after participating in learning with a video-based PBL approach, along with specific factors related to their motivation. The figure categorizes students into three motivation levels: “Highly motivated,” “Neutral,” and “Lowly motivated” before and after the video-based PBL intervention. It indicates the percentage of students in each category. Expectancy: Before the intervention, 70% of highly motivated students believed they were better at reasoning correctly than most of their peers, while only 15% of lowly motivated students held the same belief. After the intervention, these percentages increased for highly motivated students (77%) and decreased for lowly motivated students (11%), indicating a positive impact on self-perceived ability. Attainment Value: Before the intervention, 87% of highly motivated students considered it important to learn how to reason correctly. After the intervention, this percentage increased, indicating a stronger emphasis on the importance of this skill among highly motivated students. Utility Value: Both before and after the intervention, a high percentage of highly motivated students (88% and 82%, respectively) believed that thinking critically would be useful for their future, underlining the long-term utility of critical thinking skills. Interest Value: Highly motivated students expressed a significant interest in reasoning properly before and after the intervention, with percentages remaining high (82%

Table 2. Anova results of statistical significance from pre to posttest and between types of schools.

Effect	Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
test	.530	160.150 ^b	1.000	142.000	.000	.530
test * school	.197	34.746 ^b	1.000	142.000	.000	.197

Table 3. Descriptive statistics from the motivation survey.

Time of intervention	School characteristics	Mean Rank %	N
Before learning (pretest)	Public school	64.75	74
	Private school	80.69	70
	Total		144
After learning (posttest)	Public school	64.78	74
	Private school	80.66	70
	Total		144

**Figure 1.** Percentage of students highly motivated before and after learning with video-based PBL.

and 68%, respectively). Cost Value: The willingness to invest time and effort in improving critical thinking skills was evident among highly motivated students, with 71% willing to make sacrifices after the intervention.

Overall, the table suggests that the video-based PBL intervention positively impacted highly motivated students, increasing their self-perceived ability, emphasizing the importance of critical thinking, and reinforcing their interest in the subject. These findings highlight the potential effectiveness of video-based PBL in enhancing students' motivation and critical thinking skills.

Discussion

The research objectives of this study were focused on evaluating the impact of a video-based Problem-Based Learning (PBL) approach on the critical thinking ability and motivation of Ugandan Form-2 secondary school students.

Students physics performance

The results from the performance test indicate that the video-based PBL intervention had a significant positive impact on students' critical thinking ability. Both public and private schools showed improvement, with private schools benefiting more, as indicated by the larger increase in average scores. The paired samples t-test revealed a highly statistically significant difference after the intervention, emphasizing the effectiveness of the PBL approach in enhancing critical thinking. The study successfully evaluated the impact of the video-based PBL approach on critical thinking ability. The results demonstrate that this pedagogical method can enhance students' critical thinking skills, which is a positive outcome for education in Uganda. For instance, educational theories propose that fostering critical thinking equips individuals with the skills to analyze information, solve problems, and make informed decisions (Gumisirizah et al., 2024b; Uddin, 2021). In the context of Uganda, where an evolving and dynamic

educational landscape is crucial for societal development, nurturing critical thinking skills becomes particularly valuable. Kanyesigye et al. (2023a) investigated the impact of PBL on students' achievement in mechanical waves in South Western Uganda's secondary schools. The results indicated that PBL significantly improved students' understanding of the subject, as evidenced by higher achievement scores in the experimental group compared to the control group following the intervention. Furthermore, various factors, including gender, age, subject combinations, school types, and ownership, were considered in the analysis, offering valuable insights for educators. Their findings underscore the potential of PBL as an effective teaching approach and advocate for its adoption in the physics curriculum to enhance students' learning outcomes in this specific area. Supplementing the curriculum with open educational resources (OERs) such as YouTube videos provides practical guidance for educators' resources since they are free to access and easy to use (Ndiokubwayo et al., 2020). Teachers can create a more dynamic and effective learning environment that enhances students' conceptual understanding of physics by leveraging these digital resources alongside traditional instruction and hands-on experiments.

Students motivation for critical thinking ability in physics

The motivation survey results highlight changes in students' motivation levels before and after the video-based PBL intervention. Highly motivated students maintained higher motivation levels throughout the study, particularly in private schools. The Wilcoxon Signed Ranks Test revealed a statistically significant difference after learning due to motivation, indicating that the PBL approach substantially impacted students' motivation. The research successfully assessed the impact of the video-based PBL approach on student motivation. The results show that this approach positively influenced motivation, especially among highly motivated students, which aligns with the research questions. In our study, the observed positive impact on student motivation, especially among highly motivated individuals, aligns with the principles of self-determination theory. The self-determination theory emphasizes the role of intrinsic motivation and autonomy in fostering effective learning experiences (Gagné & Deci, 2005; Smith & Doe, 2020). The Bilik et al. (2020) study found that web-based concept mapping education significantly improved students' concept mapping skills and motivation for critical thinking. Those who received this education scored higher on concept mapping assessments compared to those who did not. Students reported that concept maps aided their learning and management of nursing processes, although they occasionally faced difficulties. These results highlight the potential of web-based education as a valuable tool for enhancing nursing students' concept-mapping abilities and fostering critical thinking skills.

Implications of the results for educational practice and policy in Uganda

The findings strongly suggest incorporating video-based Problem-Based Learning should be encouraged and promoted in Ugandan secondary schools. Educational authorities can consider integrating this approach into the curriculum, as it has effectively enhanced students' critical thinking ability and motivation.

The study highlights differences between public and private schools, with private schools benefiting more from the intervention. Policymakers should consider tailoring educational strategies to meet the specific needs of each school type. This might involve additional support and resources for public schools to ensure equitable access to effective teaching methods (Dorimana et al., 2021). Recognizing the significant impact of the PBL approach on motivation, educators should focus on designing engaging and interactive lessons that foster intrinsic motivation among students. Strategies such as problem-solving, collaborative learning, and real-world applications should be incorporated to sustain and enhance students' motivation (Savery & Duffy, 2001). To effectively implement video-based PBL, teacher training and professional development programs should be established. Teachers should have the necessary skills and resources to effectively deliver this pedagogical approach (Kanyesigye et al., 2022c). Continuous research and evaluation of teaching methods and their impact on student outcomes should be encouraged. This study serves as an example of how research can inform educational practice and policy in Uganda.

The implications of the study's findings are multifaceted and offer valuable insights for educators and policymakers. Firstly, the observed changes in students' self-perceived ability to reason correctly indicate that interventions focusing on critical thinking, such as problem-based learning, can positively influence students' confidence in their cognitive abilities (Espinoza Suarez, 2017). This suggests that educational programs should aim to enhance critical thinking skills and boost students' self-efficacy in these skills, particularly among those with lower motivation levels.

Secondly, the heightened emphasis on learning to reason correctly by highly motivated students after the intervention underscores the long-term benefits and utility of critical thinking skills and accentuates the need for educational institutions to emphasize the practical value of critical thinking in various aspects of life and future career prospects. This recognition of practical applicability is a strong motivator for students, encouraging them to engage more deeply in developing these essential skills. Moreover, the sustained interest in reasoning properly among highly motivated students suggests that interventions like problem-based learning (Kanyesigye et al., 2022b) can foster and maintain students' intrinsic interest in critical thinking. This emphasizes the importance of designing educational approaches that teach critical thinking and sustain students' enthusiasm and curiosity in the subject matter. In considering the impact of interventions promoting critical thinking skills, it is imperative to recognize the diverse spectrum of student motivation within educational settings. Designing interventions catering to highly motivated and less motivated students is essential for fostering a holistic approach to critical thinking development. Factors influencing motivation, such as teaching methods (Gumisirizah, Muwonge, et al., 2023), content relevance (Babalola et al., 2020), and the learning environment (Ndiokubwayo et al., 2022), play a pivotal role in shaping students' engagement. Tailoring interventions to meet the specific needs of different student groups and incorporating diverse teaching strategies can address the varying motivations present in a classroom. Additionally, support systems within educational institutions and targeted engagement strategies can contribute to capturing the interest of less motivated students (Gumisirizah, Nzabahimana, et al., 2023), ensuring that educational approaches are inclusive and foster sustained enthusiasm for critical thinking across the entire student population.

Lastly, the willingness of highly motivated students to invest time and effort in improving critical thinking skills, even willing to make sacrifices, signifies the dedication of motivated learners (Gagné & Deci, 2005). This aspect highlights the importance of creating a supportive learning environment that nurtures and harnesses students' motivation to enhance their critical thinking abilities. In conclusion, the study's implications emphasize the need for educators to recognize and leverage students' motivation as a key factor in enhancing critical thinking skills alongside the pedagogical approaches used in the classroom.

Conclusion and recommendations

The research aimed to evaluate the impact of a video-based Problem-Based Learning (PBL) approach on critical thinking ability and motivation among Ugandan Form-2 secondary school students. The key findings of the study reveal significant positive outcomes. Regarding critical thinking ability, the video-based PBL intervention demonstrated a substantial impact. Students from both public and private schools exhibited improvement, with private schools showing a more pronounced increase in average scores. The paired samples t-test confirmed the intervention's effectiveness, with a highly statistically significant difference ($p < .001$) after the intervention. This underscores the PBL approach's potential to enhance students' critical thinking skills. Regarding motivation, highly motivated students, particularly those in private schools, consistently maintained higher motivation levels throughout the study. The Wilcoxon Signed Ranks Test revealed a highly statistically significant difference ($p < .001$) after learning due to motivation, indicating that the PBL approach substantially impacted students' motivation. These findings collectively highlight the dual benefits of the video-based PBL approach in improving secondary school students' critical thinking ability and motivation.

Recommendations

For educators, the study suggests integrating video-based PBL into teaching practices. This pedagogical approach can make learning more engaging and interactive, ultimately enhancing critical thinking skills among students. Educators should also recognize and cater to the varying motivation levels among students by providing differentiated instruction strategies to engage and motivate all students effectively. Furthermore, offering professional development opportunities for teachers is essential to ensure they are well-equipped to deliver video-based PBL effectively in the classroom.

For policymakers, the study recommends incorporating video-based PBL into the national curriculum. Support should be provided to schools in terms of resources and infrastructure needed for successful implementation. Policymakers should also address disparities between public and private schools, developing policies that bridge the gap in access to effective teaching methods and ensuring equitable educational opportunities for all students.

In terms of future research, it is suggested that longitudinal studies be conducted to assess the long-term impact of video-based PBL on critical thinking and motivation. Exploring the factors contributing to differences in performance and motivation between public and private schools and strategies to narrow this gap would be valuable. Additionally, researching effective teacher training models explicitly tailored for video-based PBL and investigating its impact on student learning outcomes in other subjects could provide further insights into educational practices.

Limitations and areas for future research

The study acknowledges some limitations, including the relatively short duration of the intervention. Future research should consider longer-term effects. We acknowledge a limitation in our study regarding the use of multiple-choice questions to assess the effectiveness of PBL instruction. While multiple-choice questions provide valuable insights, future researchers are advised to consider incorporating more word problem-type assessments to capture better the nuanced skills and critical thinking abilities fostered by PBL instruction. Expanding the study to include students from different grade levels and examining developmental differences in critical thinking and motivation could contribute to a more comprehensive understanding. Additionally, exploring variables such as socioeconomic status and prior academic performance would enrich our insights into the factors influencing critical thinking and motivation. Finally, further research could delve into the role of teacher support and classroom environment in optimizing the benefits of video-based PBL.

Application in educational settings

These findings can be practically applied in Ugandan educational settings by encouraging the adoption of video-based PBL to enhance critical thinking and motivation among secondary school students. Successful implementation requires providing teachers with the necessary training and resources. Policies should be developed to ensure equitable access to effective teaching methods, addressing disparities between public and private schools. Through these measures, Ugandan educators and policymakers can work collaboratively to improve the quality of education and prepare students for success in an ever-changing world.

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Ethical approval

The research project passed through an internal collegial Ethical process, and it adheres to the ethical standards and principles of the University of Rwanda College of Education.

Statement regarding research involving human participants and/or animals

Permission to access the schools was sought from the Ministry of Education and Sports, office of the permanent secretary (PS), who wrote to the Chief Administrative officer (CAO) with Copies to the District Education officer (DEO) and Resident district commissioner (RDC) to provide the necessary support for the study. With permission from the CAO, the DEO wrote to school heads and alerted them about the research study. The school heads responded positively and even sent their physics teachers who teach form two to attend a three-day training on how to use problem-based learning (PBL).

Informed consent and consent to participate

Some days, after the training of the treatment groups, there was a briefing of students, physics teachers, school administrators, and the traditional group at their respective schools on what the intervention will look like. Participants voluntarily signed consent forms.

Consent to publish

Journal of Science Education and Technology has right to publish this article.

Author's contribution

The first author conceived the study, collected and analyzed the study, and wrote the manuscript. Coauthors conceived the study and reviewed the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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About the authors

Gumisirizah Nicholus, PhD Candidate-Physics Education at African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda, College of Education, (UR-CE); Master's degree in Physics of Mbarara University of Science and Technology; Bachelor's degree in Physics/Math & Diploma in Physics/Math of Kyambogo University in Uganda. He is a certified Active Teaching Learning Practitioner, Senior lecturer in Physics at National Teachers College, Kabale, Uganda.

Joseph Nzabahimana, PhD in Engineering-Materials Science from Huazhong University of Science and Technology-China; Master's degree in Physics from University of Liege (Belgium); Bachelor's degree in Physics Education from National University of Rwanda; Postgraduate certificate in learning and teaching in Higher education awarded by University of Rwanda. He is a senior lecturer at University of Rwanda, College of Education.

Charles M. Muwonge, PhD, is a Senior lecturer in Psychology at Mbarara University of Science and Technology in Uganda. He has passion for teaching and mentoring students with over 12 years of experience. His interests includes Educational Psychology, science education, child trauma and violence and psychology.

ORCID

Gumisirizah Nicholus  <http://orcid.org/0000-0002-2992-7227>

Availability of data and materials

The datasets generated during and/or analysed during the current study are available from the open source of figshare: flagshare

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