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Boosting learning achievement in physics among Ugandan form-2 students: effect of problem-based learning

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Abstract

Enabling students to learn smoothly at an early stage of learning is a paramount effort that African education should takeoff. This study established the effect of problem-based learning (PBL) on students' learning achievement. The participants were selected from form-2 of lower secondary schools in Sheema District, Western Uganda. Participants were randomly assigned to the treatment class with PBL instruction and the control class with content-based learning (CBL). A quantitative approach and a quasi-experimental design were used. Thus, the pretest-posttest non-equivalent quasi-experimental design was applied. A learning achievement test in simple machines was used as a data collection tool. The test was validated by experts and piloted with a split-half reliability ($r = 0.87$). Data was analysed in MS Excel and SPSS. A repeated measures

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analysis of variance revealed a very high statistically significant difference ($p < .001$) after learning in both classes. The same significance was found between PBL and CBL in favour of PBL. Classical test theory was used to present item difficulty and discrimination index. Teachers were recommended to adopt these methods with more practical hands-on activities to boost their skills and conceptual understanding.

Keywords: content-based learning, form-2 Ugandan secondary school, physics problem-based learning, simple machines, students' learning achievement

Supplementary material for this article is available [online](#)

1. Introduction

Our society needs well-trained human resource personnel with collaboration, communication, manipulation, and many others that can help them cope with new labour market demands. These skills are better developed during the teaching and learning processes. Problem-based learning (PBL) is a method of instruction that challenges learners to learn by solving real-world problems. This approach promotes learning involvement in which problems are used to encourage learners to actively engage in the learning process rather than relying on information provided by the teacher [1–3]. PBL is a student-centred approach to improving low achievement in classrooms, where the teacher acts as a facilitator. This approach helps students to recognize their current knowledge, gaps, and bridge them by applying new knowledge [4]. PBL is characterized by complex, real-world situations with no one-correct answer [5]. Students work in teams to confront problems, identify learning gaps, and develop viable solutions. The teacher acts as a facilitator, and problems lead to the development of abilities [6].

Physics teachers are key in helping learners develop the knowledge, skills, and attitudes necessary for the 21st century. This can be done by applying learner-centred pedagogy, such as PBL, task-based learning, and computer simulations [7] that focus on the role of students in an active learning process. PBL helps learners understand physics concepts and lets them know how things in the world work and why they happen the way they do [8]. Many reforms are geared to enable teachers to move from rote learning to active learning, where learners develop, research, and make reflections

that encourage student thinking abilities [2, 9]. Contrariwise, common teaching approaches such as teacher-centred or content-based methods only allow students to seek information from teachers to deliver to passive beneficiaries [10]. Thus, such a method is heavy and tiresome to teachers and boring to students. The topic of simple machines in physics needs hands-on experiences on every concept and focuses mainly on applicability in everyday life. In addition, some activities reflect real-life situations and require more conceptual understanding. Therefore, understanding is needed by students to interpret situations and correctly infer problems and find out why they continue to exist, and explain the attempts to solve them.

Freeman *et al* [11] meta-analysis provides strong evidence that active learning is a more effective teaching practice than traditional lecturing in science, technology, engineering, and mathematics (STEM) courses. The results challenge traditional lecturing as a control in research studies and support adopting active learning as the preferred, empirically validated teaching practice in regular classrooms. Theobald *et al* [12] investigated whether underrepresented students in active-learning classrooms experience narrower achievement gaps than those in traditional lecturing classrooms across various STEM fields and courses. The reported proportion of time that students spend on in-class was found to be crucial. Only classes that implemented high-intensity active learning showed a significant narrowing of achievement gaps. The study highlights the positive impact of active learning in narrowing achievement gaps for underrepresented students in STEM

courses and emphasizes the importance of implementing active-learning practices with a focus on inclusivity and student engagement [12].

PBL and other active teaching approaches entail positive student engagement and share commonalities, such as being student-centred, promoting active learning, and heightening learning outcomes. PBL is a student-centred approach that focuses on solving real-world problems. Students work in small groups to explore complex, open-ended problems, fostering independent thinking and critical problem-solving skills. Instructors take on a facilitator role, providing support, while assessment emphasizes problem-solving processes and collaboration [2]. Flipped classrooms reverse the traditional learning model by delivering instructional content outside class and dedicating in-class time to active learning activities [13]. Students engage in pre-class learning, such as lectures or videos, before participating in discussions, problem-solving, and hands-on exercises during face-to-face sessions. Collaborative learning involves students working in groups to achieve shared learning goals, promoting the social construction of knowledge [14]. Through discussions, joint problem-solving, and interactions, students gain diverse perspectives and construct a deeper understanding of the subject matter. Inquiry-based learning encourages students to generate questions, investigate topics, and seek answers through exploration and experimentation [15]. Students' curiosity drives learning through independent investigations with various active learning approaches. PBL, flipped classrooms, collaborative learning, and inquiry-based learning all focus on problem-solving, real-world applications, and group interactions.

2. Research problem

PBL promotes active learning, self-directness, independence, teamwork, skills and other cognitive abilities. All these are needed for students' learning achievement and future career readiness. However, the extent to which **PBL** influences students' learning achievement in physics remains

unclear. The aim of this study is to investigate how **PBL** can boost students' learning achievement in a physics class at lower secondary schools in Uganda. Physics is challenging for students [16], but it is essential for their future studies in science-based institutions. The Uganda National Examination Board report [17] revealed low academic achievement percentage levels in all science subjects, with Physics being the worst-performing. Physics and chemistry have below 20% performance, and nearly half of students did not achieve the minimum pass 8 grade. The assessment was based on students' ability to apply knowledge, analytical, and problem-solving skills to solve problems. Addressing students' low achievement in physics is crucial for the development of the country [18]. Traditional content delivery methods are not effective in improving students' academic achievement in physics. Therefore, there is a need to use learner-centred teaching and learning methods, like PBL, to improve students' academic achievement in physics.

2.1. Research focus

This research focuses on investigation of the relationship between the implementation of PBL and learning achievement among form-2 students studying simple machines in physics in lower secondary schools in Sheema District, Uganda. The present study contributes knowledge to the existing literature on the effect of PBL on students' conceptual learning achievement in simple machines in Physics. The study is based on social constructivism [19] since the students interact during investigation of the provided problem. Therefore, it was hypothesized that: There is no significant improvement in students' learning achievement after using PBL or content-based learning (CBL) methods.

2.2. Aim

The main of this study is to investigate how PBL can boost students learning achievement in a physics class at lower secondary schools in Uganda.

2.3. Research questions

- Does PBL boost students' learning achievement in the treatment group?
- How does students' learning achievement differ in treatment and control groups?

3. Methodology

The study employed a quasi-experimental design [20]. The data were collected quantitatively [21], and a pre-and post-test of physics learning achievement (PLA) was administered to form-2 Ugandan secondary school students (age range from 12 to 15) before and after learning the content of simple machines. Purposive sampling was used to select 829 students from eight schools. The selected schools were located in different town councils at extreme ends of the district and shared similar characteristics suitable for the study. This purposive sampling was used to assign selected schools to the treatment and control classes. Four schools were considered a control class and instructed by the traditional or common method defined as the conventional lecture method supplemented by textbooks. On the other hand, four other secondary schools employed PBL as a treatment class; and got collectively involved in a shared process of constructing knowledge.

The pre-tests were given to the treatment group and control group before the intervention. The pre-test assessed students' initial level of knowledge of simple machines in physics. Treatment or teaching intervention was given to the treatment class as PBL, while the control received a CBL treatment. Table 1 shows how the intervention was delivered in both groups. In the treatment group (PBL approach), students were engaged in an active learning process. For example, they worked collaboratively to design a pulley system to lift a heavy box to the top of a platform. They researched, investigated, and discussed possible solutions to the problem. The teaching methodology in the control group (CBL approach) was more teacher-centred. The teacher provided direct instruction on simple machines, including pulleys, through lectures, demonstrations, and visual aids. Group activities and discussions were also included, but the primary focus was content delivery and teacher-led explanations.

Teachers in the treatment group were trained on how to implement PBL, and we engaged in conversations with those in the control group to understand how traditional teaching is typically implemented. We frequently visited teachers to monitor the implementation of the intervention and provided guidance accordingly. After the treatment, both groups completed a post-test. The test items of the pre-test and post-test were similar. The purpose of the post-test was to establish whether PBL affected students' learning achievement in simple machines in physics. In this study, we refer to 'treatment class' as PBL class or a group that learned through PBL. We refer to 'control class' as CBL class or a group of students who learned through CBL.

3.1. PLA test

The test aimed to assess students' learning achievement in answering physics questions in a chapter on simple machines of physics curriculum for form-2 lower secondary schools. The test covered the chapter on simple machines in physics. Fifteen (15) objective-type questions tested students' conceptual understanding. Table 2 shows Uganda's Physics curriculum content on simple machines in form-2.

It is important to note that the test was multiple-choice and choice of a multiple-choice format was based on its ability to assess conceptual understanding and effectively provide standardized responses for analysis. Furthermore, the design of the incorrect answer choices, often referred to as distractors, is a crucial aspect of creating meaningful multiple-choice questions. These distractors are designed to reflect common misconceptions or errors students might make when attempting the questions. This helps the assessment evaluate students' correct understanding and pinpoint areas where they might have misconceptions or difficulties. These fifteen items were validated by experts in physics education for content validity, and five questions were removed. These were removed due to their clarity, alignment with the content, and potential ambiguities that could lead to misinterpretation by the students. Thus, the final test comprises ten questions, as presented in [appendix](#) (with bolded correct

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Table 1. Teaching building a pulley system in the treatment and control group.

	PBL	CBL
Teacher	Presented a problem: building a pulley system. Scenario: You and your group have been tasked with designing a pulley system to lift a heavy box to the top of a tall platform. The box is too heavy to lift directly, so you need to create a mechanical advantage using a pulley system. Challenge: design a pulley system that requires the least amount of effort to lift the box to the top of the platform. Consider the number of pulleys, the arrangement of the ropes, and the direction of force to achieve the highest mechanical advantage. Instructions: investigate the concept of simple machines, with a specific focus on pulleys and how they can be used to create mechanical advantage.	Began the lesson with a clear and concise explanation of simple machines, including pulleys. Used visual aids, diagrams, or charts to illustrate the different types of simple machines and their functions. Conducted live demonstrations of how pulleys work using simple setups or models. Show the mechanical advantage achieved by using pulleys and how they make work easier.
Students	Worked collaboratively with group members to brainstorm ideas for the pulley system design. Conducted research and gathered information on different types of pulley systems and their advantages. Drew a diagram clearly indicated the arrangement of pulleys and ropes. Estimated the force required to lift the box without the pulley system and compared it with the force required using the pulley system design. Discussed the advantages and disadvantages of design, and identified any potential improvements. Presented findings and pulley system design to the class, explained how it works and the principles behind it.	Discussion on the principles of pulleys.

Table 2. Uganda physics curriculum content on the topic of simple machines in form-2.

	Topic included
1	Concept of simple machines, explaining the significance of using a machine,
2	Levers; classes of levers, application of levers
3	Pulley system; types of pulleys, application of pulleys, mechanical advantage, velocity ratio, and efficiency
4	Inclined planes; application of inclined planes, mechanical advantage, velocity ratio, efficiency
5	Wheel and axle; understanding wheel and axle, application, velocity ratio
6	Gears; understanding how gears simplify work, application, velocity ratio
7	Improving the efficiency of a machine

Table 3. Levene's test for equality of variances.

Test equal variances assumed		F	Sig.
Pre-test	Yes	.000	.986
Post-test	Yes	.012	.975

answers). We measured the reliability of these items with a split-half method and got a high reliability of $r = 0.87$. The split-half reliability assumes that the two halves of the test are equivalent in difficulty and content [22]. The test was administered under similar conditions for all the selected schools. The test was marked out of ten and scaled to 100%. The higher the score earned on this test, the higher the learning achievement, and the higher the number of students who were able to answer a test item, the higher conceptual understanding was achieved.

3.2. Ethical consideration and permission to access the schools

The research project passed through an internal collegial Ethical process and adhered to the ethical standards and principles of URCE's research and innovation unit. 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 senior two (S.2) or form-2 to attend a three-day training on PBL. Some days, after the training of the treatment group, there was a briefing of students, physics teachers, school administrators, and the control group at their respective schools. Teachers and students (with parental consent) willingly participated in the research study after signing informed consent forms, indicating their full awareness of the study's purpose, procedures, potential risks, and benefits. Students did not write their names on the test papers, as was highlighted during the briefing to ensure anonymity.

3.3. Data analysis

Microsoft Excel 2016 records data and computes basic analyses such as sum and percentages. IBM SPSS 25 was used to compute inferential statistics such as p -values and effect sizes. These data were used to compare our teaching interventions (PBL and CBL). As the PLA test comprised ten questions, each student's answer choice was recorded, and then one score was awarded in case the choice was correct and zero otherwise. We then computed the sum of the score and their corresponding percentages on the one hand. On the other hand, we computed the sum of students who got each question correct and their corresponding percentages. This analysis revealed the conceptual understanding of students among PLA test items. Before using parametric tests, we explored the assumptions and found that sample size (>30), type of data (continuous), and equality of variances (Levene's test $p > .05$) were in agreement with such analysis. Table 3 shows Levene's test of equality of variances between treatment and control classes.

Choosing whether to use analysis of variance (ANOVA), analysis of covariance (ANCOVA), or t -tests, we computed an independent sample t -test and found that both classes were at the same level before embarking on the intervention. Thus, repeated measures ANOVA was used to measure the significant difference from pre-to post-test between the treatment and control classes.

There was a shift due to teaching intervention (implementation of PBL). Meaning that students obtained higher scores in posttest after implementation of PBL than in pretest.

4. Results

4.1. Analysis of mean score difference

Table 4 displays mean scores and standard deviations before and after teaching and learning simple machines. Students in both treat-

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Table 4. Group statistics.

	Class	N	Mean	Std. deviation	Std. error mean
Pre-test	Treatment class	482	35.3112	14.76097	.67234
	Control class	347	36.3112	14.23161	.76399
	Total	829	35.7298	14.54144	
Post-test	Treatment class	482	57.5311	17.02157	.77531
	Control class	347	51.7579	17.01985	.91367
	Total	829	55.1146	17.24763	

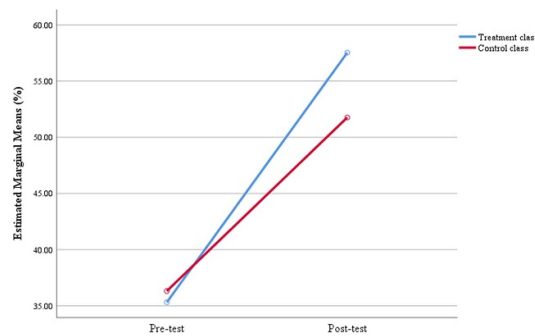


Figure 1. Mean score shift from pre-to post-test among treatment and control classes.

Table 5. Tests of within-subjects contrasts in physics learning achievement mean scores.

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Test	143 121.505	1	143 121.505	557.611	.000	.403
Test * treatment-control	4627.898	1	4627.898	18.031	.000	.021
Error (Test)	212 265.226	827	256.669			

ment and control classes got quite similar scores on the pre-test of 35.31% and 36.31%, respectively. These classes showed scattered scores after teaching intervention. The treatment class got 57.53%, while the control class got 51.75%.

There was a normalized gain of 34.34% in the treatment class and 24.25% in the control class. In fact, there was a 10.09% normalized gain difference from the control to the treatment class.

Table 5 shows that there was a very high statistically significant difference ($p < .001$) before and after teaching intervention with a medium effect size ($\eta = .403$). Likewise, there was a very high statistically significant difference ($p < .001$) with a small effect size ($\eta = .021$) between the

treatment and control group in favour of the treatment group.

4.2. Analysis of score distribution

Further analysis of the histogram displays students' score distribution to check the performance of classes. The lowest and highest scores were 0.00% and 80.00% in the treatment class (with a 14.76% standard deviation) before teaching intervention (figure 2). Likewise, the lowest and highest score was 10.00% and 80.00%, respectively, in the control class (with a 14.23% of standard deviation) before the teaching intervention.

Figure 2 displays a histogram of score distribution in the post-test too. The lowest and highest scores became 10.00% and 100.00%,

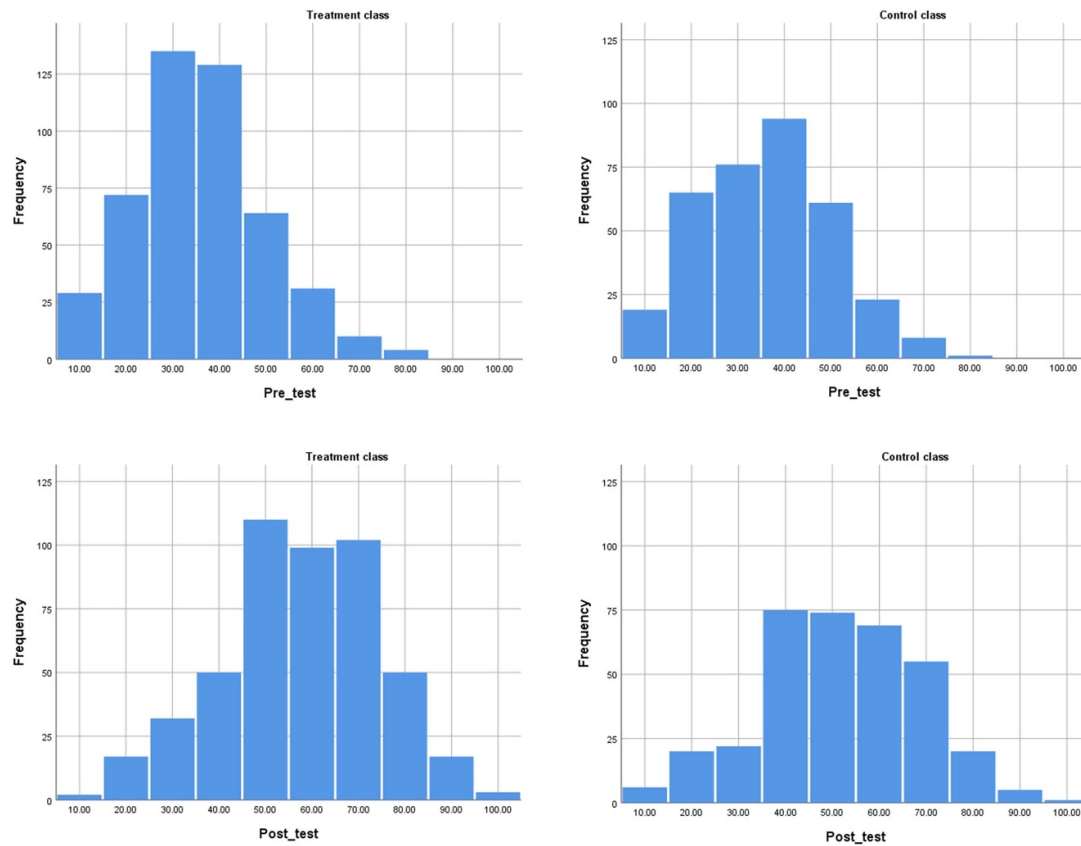


Figure 2. Histogram of students' pre-test score (top) and post-test score (bottom) distribution in treatment class (left) and control class (right).

respectively, in the treatment and control classes (with a 17.02% of standard deviation) after teaching intervention.

4.3. Analysis of test items

Classical test theory helped us to analyse question by question in the physics PLA TEST. Figure 3 displays the difficulty index or the number of students (in decimals) who well performed the items in each stage of intervention and each class. The index ranges from 0 to +1.

The difficulty index was found to be 0.35 and 0.36 in the pre-test of the treatment and control class, respectively, while it became 0.58 and 0.52 in the post-test of the treatment and control class, respectively. Both interventions showed a good performance in Q1, Q2, Q4, Q5, Q8, and Q10,

as more than 35% of students performed them after learning the content of simple machines. Q3 and Q6 were found to be easy for the treatment group after learning via PBL, as more than 85% of students correctly answered them. Q7 and Q9 showed a persistent poor performance as students who performed them correctly were found to be below 35% even after teaching intervention.

Likewise, figure 4 displays the discrimination index or the item power index, a comparative index between how the high-performing students did on an item versus low-performing students in each intervention stage and each class. The index ranges from -1 to $+1$.

The discrimination index was found to be 0.35 in the pre-test of both the treatment and control classes, while it became 0.40 and 0.41 in the post-test of the treatment and control classes, respectively. The minimum distribution cut-off is

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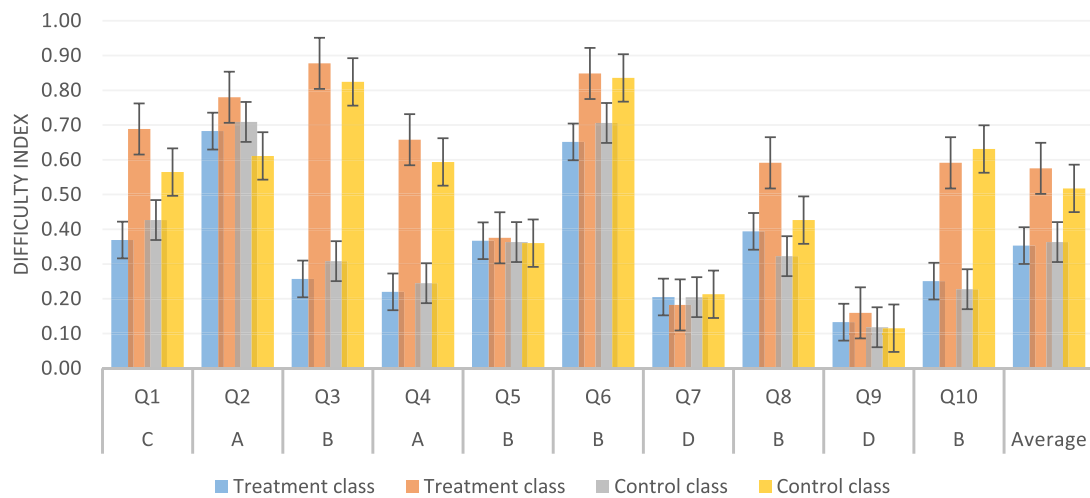


Figure 3. Difficulty index of physics learning achievement test.

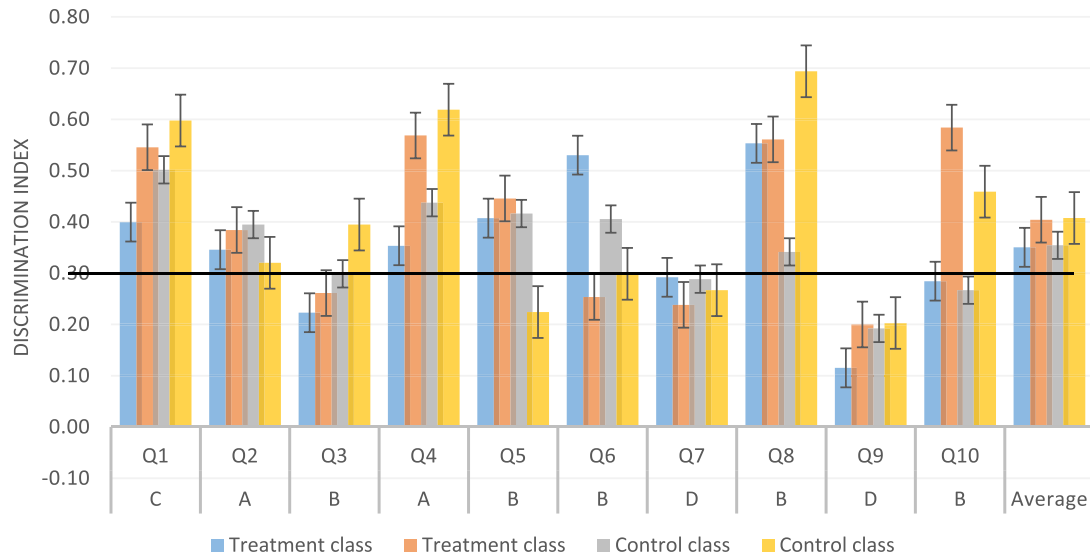


Figure 4. Item discrimination index of physics learning achievement test.

0.20. Discrimination of 0.30 and above is interpreted as good, while 0.6 and above is interpreted very well. Q1, Q2, Q4, and Q8 were found to discriminate between high and low achievers before and after any treatment despite the treatment or control class. Thus, the discrimination index was above the 0.30 cut-off. Students similarly performed Q7 and Q9 since their discrimination index was below 0.30. PBL allowed high and low-performing students to perform Q6 similarly,

while CBL allowed these students to perform Q3 similarly.

5. Discussion

This study revealed a significant improvement in form-2 students' learning achievement after implementing both PBL and CBL instruction in lower secondary schools of Sheema District. The changes in learning achievement in the

treatment class were significantly greater than those in the control class ($p < .001$) as it was not before intervention. Therefore, this compromises the social constructivism theory [19, 23] that guided this study, and the stated null hypothesis was rejected. Findings indicate a significant improvement in students' learning achievement for the group that applied the PBL method of instruction after completing the study on simple machines compared to the group that used talk and chalk, dictating notes, and other teacher-centred approaches CBL. Such improvements were shown in previous studies. For instance [24], highlighted PBL as an approach that helps teachers use time adequately and helps students develop conceptual understanding and reasoning that enable them to face real-life challenges. Likewise, a study done in Uganda has proven a positive effect of PBL instruction on secondary school physics students in understanding electromagnetic waves [25] and mechanical waves.

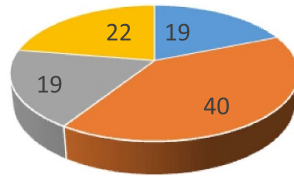
Specifically, our study built the gap in the literature that documented the effect of PBL in learning and understanding the mechanisms of simple machines. Such basic mechanics topics are crucial for students to develop students' skills and solve problems arising in real-life situations. We concur that if students in early secondary education understand how simple machines work, they will grasp advanced topics without any problem. Thus, training junior students to think critically is crucial for teachers and their society. The current study has shown that content and PBL can enhance students' conceptual understanding. This was shown by the item analysis where students in both classes performed failed items (in pre-test) greatly and on the same level after being introduced to these instructions. This shows how Ugandan teachers are doing great work to the extent that a so-called teacher-centred, here-defined CBL can make learners learn effectively as so-called learner-centered, here-defined PBL does. This was also revealed in the study of remediating difficulties in understanding mechanical waves among Ugandan high school students.

Another uniqueness of our study was framed in analysing answer choices of the item by item

used in the PLA test. The discrimination index is a basic measure of an item's validity because it measures an item's ability to discriminate between those who scored high and those who scored low on the total test. Its positive value indicates good discrimination, a value near zero indicates little discrimination, and a negative value indicates that the item is easier for low-scoring participants. Thus, values close to 0 inform that most students performed the same on an item. The pre-test showed that Q3, Q4, Q7, Q9, and Q10 had misconceptions before intervention. However, these misconceptions were remediated except for Q7 and Q9, which persisted in misconceptions after the intervention. For instance, Q3 asked suitable expressions of the efficiency of a machine among (a) VR/MA , (b) $(MA/VR) \times 100$, (c) $(VR/MA) \times 100$, and (d) $(VR \times MA)/100$. The correct answer was (b) that the efficiency of a machine is the ratio of mechanical advantage and velocity ratio times 100; however, most students answered (c) in both classes. This may be interpreted that students were not aware of the correct formula and were hesitant before learning the appropriate formula. Likewise, Q4 asked to find the efficiency of a machine that requires an effort of 100 N to raise a load of 10 000 N. If its velocity ratio is 500, the answer would be 20%, but students answered 5%. This might be caused by inverting the formula. And the reason for answering these Q3 and Q4 wrongly is found to be the same. Q10 asked to choose the correct formula for velocity ratio. Many students in PBL class answered that the formula of velocity ratio is the distance moved by the load divided distance moved by the effort, and students in CBL class answered that it is mechanical advantage times velocity ratio instead of distance moved by the effort dividing distance moved by the load. Students in PBL class tried their best only that they thought reversely. Students in CBL answered it randomly because there was no way to provide an answer using a component of the asked question.

However, as we said above, these misconceptions were remediated after learning the content of simple machines, luckily in both classes. Q7 persisted even after learning. It asked to make a true statement about a pulley system with two pulleys in the upper and two in the lower blocks.

Q7. Which of the following statements is /are true about a pulley system that has 2 (two) pulleys in the upper block and 2 (two) pulleys in the lower block?



- A (i) and (ii) only ■ B (iii) and (iv) only
- C (i), (ii) and (iii) only ■ D (ii), (iii) and (iv) only

Figure 5. Question-related to the pulley system.

The statements are (i) the Mechanical advantage of the system increases up to a limit as the load increases, (ii) the efficiency of the system is less than 100, (iii) the Mechanical advantage may exceed four depending on the load, and (iv) the efficiency of the system will decrease as the load increases. Likewise, the efficiency of the pulley system will decrease as the load increases. Increasing the load will add to the friction, thus reducing the efficiency of the system. The ideal mechanical advantage will not change since the MA neglects friction. Students persistently answered (B) instead of (D). They still did not understand that the system's efficiency was less than 100 (ii). And this rose in both classes. This might have probably been caused by students thinking of an ideal machine with 100% efficiency without any loss. Still, future studies should look at why both CBL and PBL cannot handle this problem. For example, Q9 asked to select features for second-class levers, (i) load is between fulcrum and effort, (ii) effort moves farther than the load, (iii) multiplies effort but does not change its direction, and (iv) effort moves shorter than the load. Both classes select (A) before and after treatment instead of (D). The number of students who answered the wrong answer after learning has, in fact, increased in both class D). Figure 5 is an example of how students in PBL class answered Q7 after learning the content of a simple machine.

Second-class levers such as staplers and wheelbarrows multiply effort force but do not change their direction. Effort moves longer than the load, not shorter than the load. It is, in fact, not surprising to confuse these properties because it requires students to practice time by time before understanding the working principles. This is why [26] recommended hands-on activities. Thus, teachers teaching such simple machine topics should matter on students' practices via improvised activities [27] or project-based learning [28].

6. Conclusions

This study intended to measure lower secondary school students' achievement in simple machines through PBL in Uganda. The study employed a large sample of 829 students, and a quasi-experimental design was used to compare students who learned with PBL and those who learned with CBL. Both PBL and CBL were found to promote conceptual understanding through PBL was super to CBL. Since conceptual understanding helps learners integrate scientific knowledge into real-life experiences, PBL should be employed in teaching and learning physics. Physics teachers need to undertake regular training and continuous professional development courses on learner-centred methods and techniques that allow the learners to develop more abilities, understanding of the subject even interpreting real-life phenomena after school. Further studies can be done with more students from other classes like form three (3), form four (4) in the district, and even considering other districts in Uganda. We recommend that future studies should establish effectiveness of PBL in assessing skills acquired during teaching and learning in a physics class.

Data availability statement

Data related to this article are free and available at figshare repository: <https://doi.org/10.6084/m9.figshare.23712912.v1>

All data that support the findings of this study are included within the article (and any supplementary files).

Acknowledgments

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Ethical statement

The study followed ethical guidelines to ensure the protection and welfare of participants. Ethical clearance was obtained from the University of Rwanda-College of Education, Directorate of research and innovation, Mbarara University of Science and Technology-Research Ethics Committee-(MUST-REC) and final approval from Uganda National Council of Science and Technology-(UNCST). In addition, Permission to access the schools was sought from the Ministry of Education and Sports, office of the PS who wrote to District authorities to render necessary support to the study. The participants were below 18 years (Uganda law). It was done according to established protocols for research involving subjects. The purpose of ethical clearance was to ensure that the study design, data collection, participant interactions were consistent with ethical standards. Therefore, informed consent to participate in the study, and for the results to be published, was obtained from participants (or their parent or legal guardian in the case of children under 16) for all research involving human subjects. This statement confirms that the study was carried out in accordance with the principles outlined in the ethical policy (see <https://publishingsupport.iopscience.iop.org/questions/ethical-statements>).

Implications

The study findings have implications to educational institutions and curriculum designers by promoting students' learning achievement through PBL. The study results provide empirical

evidence on effectiveness of PBL in enhancing students' learning achievement across different educational levels, supports decisions-making processes for educators and administrators when considering the implementation of PBL as a pedagogical approach. In addition, the study findings can guide instructional practices by highlighting specific aspects of PBL that contribute to the improvement of students' learning achievement for academic success, lifelong learning and participation in the world of work.

Appendix. Physics Learning Achievement (PLA) Test (correct choice are in bold font)

School.....
Subject: Physics Class: S.2 Time: 30 min.

This test consists of **10 (ten)** objective-type questions; every question has four given responses, out of which one answer is correct. If a student circles the correct answer, then he/she is given one mark, and if he/she circles a wrong answer, zero is given. A total of 10 marks. Students should circle one correct answer.

1. The efficiency of a machine that raises a load of 200 N through 2 m when an effort of 100 N moves through 8 m, is
A. 0.5%
B. 5%
C. **50%**
D. 60%
2. A block and tackle system has 4 pulleys in the upper fixed block and 3 pulleys in the lower movable block. What is the velocity ratio of the system?
A. 7
B. 8
C. 4
D. 3

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3. The suitable expression of the efficiency of a machine is given by:
 - A. VR/MA
 - B. **$(MA/VR) \times 100$**
 - C. $(VR/MA) \times 100$
 - D. $(VR \times MA)/100$
4. Find the efficiency of a machine that requires an effort of 100 N to raise a load of 10 000 N. If its velocity ratio is 500.
 - A. **20%**
 - B. 1%
 - C. 50%
 - D. 5%
5. A pulley system with a velocity ratio of 6 is used to lift a load of 250 N through a distance of 3 m. If the effort applied is 50 N. How much energy is wasted?
 - A. 125 J
 - B. **150 J**
 - C. 250 J
 - D. 750 J
6. A machine of velocity ratio (VR) is to raise a load whose weight is 200 N. The effort required is 50 N. Calculate the Mechanical Advantage of the machine
 - A. $\frac{1}{4}$
 - B. **4**
 - C. 5
 - D. 10
7. Which of the following statements is /are true about a pulley system that has 2 (two) pulleys in the upper block and 2 (two) pulleys in the lower block?
 - (i) the Mechanical advantage of the system increases up to a limit as the load increases
 - (ii) the efficiency of the system is less than 100
 - (iii) the Mechanical advantage may exceed 4 depending on the load
 - (iv) the efficiency of the system will decrease as the load increases
 - A. (i) and (iv) only
 - B. (iii) and (iv) only
 - C. (i), (ii) and (iii) only
 - D. **(i) and (ii) only**
8. Which of the following explains how a machine does work?
 - (i) increasing the size of the load compared to the size of the effort
 - (ii) increasing the distance moved by the load compared to the distance moved by the effort.
 - (iii) changing the direction of the effort
 - (iv) decreasing the size of the load compared to the size of the effort.
 - A. (i) and (iv) only
 - B. **(i), (ii) and (iii) only**
 - C. (i), (ii) and (iv) only
 - D. (i), (ii) and (iv) only
9. For the second-class lever,
 - (i) load is between fulcrum and effort
 - (ii) effort moves farther than the load
 - (iii) multiplies effort but does not change its direction
 - (iv) effort moves shorter than the load
 - A. (i) and (iv) only
 - B. (ii) and (iv) only
 - C. (iii) and (iv) only
 - D. **(i) (ii) (iii) only**
10. The correct formula for velocity ratio is
 - A. Distance moved by the load/Distance moved by the effort
 - B. **Distance moved by the effort/ Distance moved by the load**

- C. Mechanical advantage x velocity ration
- D. Velocity ratio x load

Summary: Answers, 1C, 2A, 3B, 4;A, 5B, 6B, 7D, 8B, 9D, 10B

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