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RESEARCH ARTICLE

Effect of problem-based learning on Ugandan secondary school physics classroom practices: an observational study

[version 1; peer review: awaiting peer review]

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Abstract

Background: Regular class observations are common ways of monitoring what happens inside classrooms during the teaching and learning processes. From the start of 2020, the Ugandan Education System introduced a new curriculum focusing on active learning methods which foster learner-centered approaches, including Problem-Based Learning (PBL). However, this new curriculum is now only emphasized in the lower classes (grades eight and nine), and teachers of the upper classes are still at liberty to use methods of their choice. This study documented the effect of problem-based learning on Ugandan secondary school physics classroom practices using a Reformed Teaching Observation Protocol (RTOP).

Methods: The study followed a quantitative approach with a quasi-experimental design employing cross-sectional survey techniques. The study was carried in 19 secondary schools, both government and private, in Mitooma District, southwestern Uganda. The participants were 419 13th-grade physics students of 2020/2021 school year together with 22 teachers. Professional training in implementing and assessing PBL lessons were offered to some teachers (experimental group), who were compared to those who did not receive the training (control group). The standard and validated international RTOP was used to observe 152 physics lessons. Microsoft Excel 2016 was used to compute descriptive analysis, while IBM SPSS 25 was used to compute inferential statistics.

Results: The results indicated that teachers in the experimental group effectively taught their classes using PBL and learners were more active compared to the control group. Female teachers showed a statistically significant difference compared to their male teachers in reformed teaching of physics, while no significance was found between government and private schools.

Open Peer Review

Approval Status *AWAITING PEER REVIEW*

Any reports and responses or comments on the article can be found at the end of the article.

Conclusion: Giving teachers professional training is key to effective classroom practices. We recommend teachers to use PBL in teaching, policymakers train teachers on its implementations, and researchers investigate its effect on other subjects with RTOP or other standard observation protocols.

Keywords

classroom observation, physics class, physics teacher, problem-based learning, Uganda

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Introduction

Background of the study

Until 2020, the Ugandan education system has basically been using a knowledge-based curriculum. This kind of approach is teacher-centered; usually, teachers tend to focus on getting the syllabus completed, and they are the owners of knowledge, leaving learners to serve as just recipients of Knowledge (Nzeyimana & Ndiokubwayo, 2019). However, students have been found to appreciate more teachers who motivate and involve them during learning (Ukobizaba *et al.*, 2019). Thus, all teachers need to adopt active learning methods such as problem-based learning to enhance problem-solving and critical thinking skills, innovation, and creativity among learners (Ndiokubwayo *et al.*, 2020a).

Problem-based learning is a method comprised of challenging real-life problems with no immediate solution. Learners are first put into groups of five to six members with a chair person and a secretary; they are then presented with a real-life problem by the teacher. They breakdown the problem in order to understand it, devise various ways of solving the problem, choose and implement the best way to solve it, and then they check the appropriateness of the solution (Dorimana *et al.*, 2021). This method engages students actively and equips them with the skills of manipulating hands-on tools, participating in discoveries, and collaborating with their teammates. The teacher, in this regard, acts as an observer, guide, and collaborator, orienting the students to the lesson's objective (Ndiokubwayo *et al.*, 2020a).

Naturally, people differ in personalities and when participating in the teaching and learning process, they act as individuals. Some of them may even lack up-to-date information concerning appropriate techniques and approaches in dealing with advanced characteristics of teaching and learning (Barrogo, 2020). All these differences in personalities and technicalities in teaching methodologies significantly relate to students' academic achievement as pointed out by Zaare (2013). Additionally, there is a scarcity of documentation of African classroom practices, especially physics teaching in Uganda. Thus, this study employed the Reformed Teaching Observation Protocol (RTOP) to capture and characterize what happens during classroom implementation of problem-based learning.

Traditional teaching and problem-based learning instructions

Conventionally, teacher-centered methods have been commonly used during teaching where teachers possess full autonomy over classroom activities (Mpho, 2018) and learners are perceived as mere recipients of knowledge (Karamustafaoglu, 2009). Teacher-centered methods of instruction according to Hill (2002) can be in form of chalk and talk/direct instruction commonly referred to as lecture method. Teachers employing this teaching approach focus on how to organize, structure and present the subject content in a way that makes it easier for the students to understand (Sari *et al.*, 2006); students are required to listen attentively as they assimilate the information (Hill, 2002). The lecture method commonly employed in the traditional teaching over-emphasizes problem-solving instead of conceptual understanding (Richardson, 2004). Students under this method may correctly apply the formula when solving a problem due to memorization but may lack understanding of the basic principles (Mioković *et al.*, 2012). This approach causes students to lose sight of the educational goals compared to when they are involved in constructing their own knowledge (Mpho, 2018).

Classroom observation practices

When researchers want to observe the communicative features of either students or teachers, or both, they can use observation protocols (Vidhiasi *et al.*, 2018). Leary (2013) defines 'observation' as assessing teaching and learning and developing teachers' skills and knowledge. They are guides upon which teachers make self-evaluations in order not only to improve classroom practices but also school management as a whole (Zaare, 2013). A classroom observation tool is not meant to threaten teachers but rather to aid them to plan their classroom activities and other professional phases (Barrogo, 2020).

The RTOP deals with the level to which teachers' classroom practices match those expected under learner-centred instruction (Sawada *et al.*, 2000). Reformed teaching refers to those classroom practices that lead to high scores on the RTOP (MacIsaac & Falconer, 2002). Formation of the RTOP focused on three major components: learner-centredness, inquiry-oriented, and standards-based (Sawada *et al.*, 2000). This therefore provides the relationship between reformed teaching and the magnitude of learning. Comparing with other observation protocols, RTOP offers the advantage of being inductive and easy to compare with other observation protocols, and different observers can easily confirm it which gives it a greater inter-observer reliability (Sawada *et al.*, 2000).

In their article, MacIsaac *et al.* (2001) assessed the practicability of the use of a measurement tool to enhance teachers' self-reflectiveness. The RTOP tool was employed to understand and define reform teaching. The tool assesses three main pedagogical domains: lesson design and implementation, propositional and procedural knowledge, communicative interactions, and student-teacher relationships. This tool greatly fits the principle followed in this study which focused on

science in general and particularly physics, and exclusively on reform rather than general properties including class management, lesson closure, short to administer, high inter-rater reliability, and easily available training and reference manuals (MacIsaac *et al.*, 2001).

According to Zaare (2013), handling observation protocols needs one to have a high level of professional ethics and highly objective. During observation, the observer should sit in the back or to the side and should not interrupt the flow of the class. He/she should note down and analyze the beginning activities such as how the room is arranged, and also identify the different areas of the environment which need learners to use specific procedures (Zaare, 2013). They should generally take note of all things seen and heard being aware their prior experiences, personal style, and personal worldview and biases should not be reflected in their perceptions. Observers should try to step back and observe again with an utmost 'empty' mind, that is, empty of their prejudgments (Zaare, 2013).

Teachers' attitude towards classroom observations

Barrogo (2020) analyzed the teachers' perception of the standardized classroom observation tool, and his results showed that in eight out of the 10 statements, teachers strongly agreed that the classroom observation tool serves as a guide for them to assess their performance and plan for their improvement, thus, enhancing their preparation and competency. In Atkinson and Bolt's (2010) study about using teaching observations to reflect upon and improve teaching practice in higher education, the staff became more interested in undergoing classroom observation as they helped them reflect on their classroom practices. They recommended the process of classroom observation be routine, and that ongoing follow-up should occur (Atkinson & Bolt, 2010).

Theoretical framework

Piaget (1970) pointed out that children study well by doing as they discover their environment. In this regard, Aderonmu and Obafemi (2015) recommended that in teaching science, learners should be presented with meaningful activities. According to Demirci (2009), and Yilmaz and Ince (2012), learners should be motivated to something in the process of learning rather than only just learning something. The theory of social-constructivism developed by Vygotsky and Cole (1978) thus guided this study. The theory proposes that learners need to create their own knowledge and also be in position to collaboratively use their skills for realization of lesson objectives. Believers of this theory content that since learners have the ability to develop their own understanding via negotiation inside their social setting, teachers thus do not need to transfer knowledge from themselves to the learners. The teacher in this theory is considered to be a facilitator rather than an instructor during teaching and learning process.

Study questions

This study was guided by two research questions:

1. Is there a statistically significant difference in physics classroom practices among teachers who use Problem-Based Learning instruction and those employing Traditional methods?
2. Do factors such as teachers' gender and school type statistically influence physics classroom practices?

Methods

Ethical procedure

A proposal was first developed and approved by the academic committee of the University of Rwanda, College of Education, and was thereafter ethically cleared (Ref: 03/DRI-CE/067/EN/gi/2020) by the university's research and innovation office. Permission to conduct research in Uganda was given by the permanent secretary Ministry of Education and Sports – Uganda (Ref: C307/2021). The study did not isolate particular groups, such as those living with HIV or impaired persons, but all grade 13 physics students that belonged to the participating schools were part of the study without any discrimination. A week before the start of data collection, the authors briefed the participants about the aim of the study, and those willing to participate signed written informed consent letters. They were also informed that although publications may arise from the data to be collected, their identities were to be kept anonymous at all times. Thus, no additional consent was obtained for publication purpose and this does not distort any scientific meaning. A few of the participants who were still below 18 years at that moment were asked to first consult their parents, who in turn consented on their behalf by signing the same forms. Each participant was given a code and was referred to only by that code. No monetary compensation was given to participants. Participants were free to withdraw from the study at any time without penalty and were also free not to answer any questions or respond to any research situations if they chose to.

Research design

A quasi-experiment research design (Fraenkel *et al.*, 2012) was used in which the participants being observed were either in the experimental group (those trained in the problem-based learning process) or in the control group (those not trained in the problem-based learning process), and the observations took place naturally in the classrooms.

Sample and sampling techniques

During proposal development, the first author approached the District Education Officer (DEO) Mitooma District located in southwestern Uganda and requested for a list of all secondary schools in the district. We have randomly selected 19 secondary schools (Eight government owned and 11 privately owned) at a 95% confidence interval with reference to Krejcie and Morgan (1970). A lotto was then made from which 10 schools were randomly picked and put under the experimental group while those which were not picked (11 schools) formed the control group. All grade 13 physics students in the academic year 2021 participated as cohorts. Physics teachers that happened to be teaching in the schools under the experimental group were then trained in how to implement a Problem-Based Learning (PBL) lesson after which they proceeded with implementing PBL in the physics classrooms. The authors then proceeded to observe the teachers both in the experimental and control groups as they taught. In total, 419 grade 13 physics students together with their teachers were observed. Specifically, 72 observations were made in classrooms instructed by teachers who had been trained in PBL process, while 80 observations were made on classrooms instructed by teachers who did not attend the training in PBL process. The whole class of grade 13 physics students in each of the selected schools participated as cohorts.

Instrument of the study

Data was collected using a Reformed Teaching Observation Protocol (RTOP) as a standardized tool developed by Sawada *et al.* (2000) and accessible on PhysPort.org. The tool assesses interactive teaching, and it can be used for different levels of education, including graduate, upper and lower secondary, college, among others. At the start of data collection, the interobserver reliability was checked. One lesson was observed by two observers and their ratings were then compared. Across all the 25 RTOP items, an agreement of 96% and 0.82 Kappa statistics was obtained between the two observers. There was no measure of observer error within the RTOP data since no interrater reliability was obtained during the course of the study.

Data collection procedure and explanation of teaching intervention

All the teachers in schools under the experimental group were first trained in how to effectively implement PBL in the classroom, unlike those in the control group. This selective training was to enable authors to assess and document if professional training in PBL had an effect on teachers' classroom practices. The training given to the teachers in schools under the experimental group was entitled "Learning actively in the classroom: How to use Problem-Based Learning (PBL)" (Kanyesigye *et al.*, 2022c; 2022g). It was aimed at equipping teachers with knowledge of what PBL is, guiding them to generate good PBL questions and be able to conduct a real classroom PBL lesson, and also skill them in assessing PBL lessons.

When the authors reported to schools for data collection, the teachers were informed that a scientific study was taking place and that the authors would be attending the lessons with them to observe how teaching was taking place and they were also made aware that the observations would be recorded for purely academic and possibly publication purposes. In total, 152 lessons were observed (72 observations on classes taught by teachers who were trained in PBL and 80 observations on classes taught by teachers who were not trained in PBL).

In one of the PBL classes, teachers in the previous lesson had presented a problem to the groups: Discuss the fact that knowledge of waves can be used to mitigate energy crisis in Uganda. In one the groups, they formed other sub-questions in their attempt to solve the given problem: What are waves? How is the formation/propagation of waves related to energy generation? What technologies exist that can increase amount of energy generated from waves? So, each of the above questions was researched on and presented by the different members of the groups. They concluded that waves if well tapped can be a potential source of energy (wind energy, solar energy, Hydro Electric Power from water waves, *etcetera*) hence a remedy to the energy crisis not only in Uganda but worldwide. In most of the classes taught by teachers who did not attend the training in PBL, they would immediately after entering the class start dictating notes to the students. At the end of the sub-topic, they would give guiding questions to the students. But the teachers tended not to follow up on whether the students would answer the given questions or not. Again, Students would also be allowed to ask for clarification during the lesson and the teacher would solely answer the questions raised by the students (raw data can be accessed via Kanyesigye *et al.*, 2022b; 2022f).

Data analysis

We analyzed data with Microsoft Excel 2016 and IBM SPSS Version 25.0 (open-access alternative statistical software to SPSS is PSPP). Descriptive statistics were used to compute mean scores and standard deviations (STD), while inferential statistics were used to measure the significant difference between control and experimental groups and other variables. Since the data were ordinal data, we changed them into continuous data by averaging all rated data for each RTOP item across several teachers. Descriptive tables and figures were drawn, and these mean scores were taken to SPSS spreadsheets to compute the significance of variables. There were 72 lessons observed in the experimental group and 80 lessons observed in the control group. Prior to computing inferential statistics, we checked if we could use parametric tests such as the t-Test. We tested normality of data and equality of variance, but these assumptions were found to violate the use of parametric tests since Kolmogorov-Smirnov of normal distribution, and Levene’s Test of equality of variances showed a significant difference ($p < .05$). Thus, the data were not normally distributed, and variances were not equal across various variables.

Results

This sections simultaneously presents teachers’ demographic information and data related to two research questions: is there a statistically significant difference in physics classroom practices among teachers who use Problem-Based Learning instruction and those employing Traditional methods; and do factors such as teachers’ gender and school type statistically influence physics classroom practices?

During the study period, only three students missed one or two lessons due to illness, however, they were able to join back after their health improved. Therefore, all the 419 intended grade 13 physics students together with the 22 physics teachers successfully completed the study. The experimental group (10 schools) consisted of 231 students and 11 teachers, while the control group (9 schools) constituted of 188 students and 11 teachers. Table 1 summaries the demographic information of the teachers.

From Table 1, it can be seen that majority of the schools were privately owned in both the experimental (54.4%) and control (63.6%) groups. In the experimental and control groups, 63.6% and 54.5% of the schools participated in both pretest and posttest respectively. Most of the participants (72.7%) in both groups were males; had a teaching experience of 5–10 years (63.6% for experimental and 81.8% for the control group); and had a bachelor’s degree (90.9%) as their highest academic qualification.

Figure 1 displays the score distribution of the experimental group. It shows that the scores skewed on the right side.

Likewise, Figure 2 displays the score distribution in the control group. It can be seen that data are scattered, and the kurtosis is low. From both figures, classroom observation practices are better in the experimental than in the control group because the scores tend to be maximum (4/4).

Table 1. Teachers’ demographic information.

Item	Category	Experimental group		Control group	
		f	%	f	%
School ownership	Government owned	5	45.5	4	36.4
	Privately owned	6	54.5	7	63.6
Pretest versus posttest	Class exposed to both pretest and posttest	7	63.6	6	54.5
	Class exposed to only posttest	4	36.4	5	45.5
Sex of the teacher	Male	8	72.7	8	72.7
	Female	3	27.3	3	18.2
Teaching experience	<5 years	2	18.2	1	9.1
	5-10 years	7	63.6	9	81.8
	>10 years	2	18.2	1	9.1
Teachers’ academic qualification	Diploma	0	0.0	0	0.0
	Bachelors	10	90.9	10	90.9
	Postgraduate	1	9.1	1	9.1

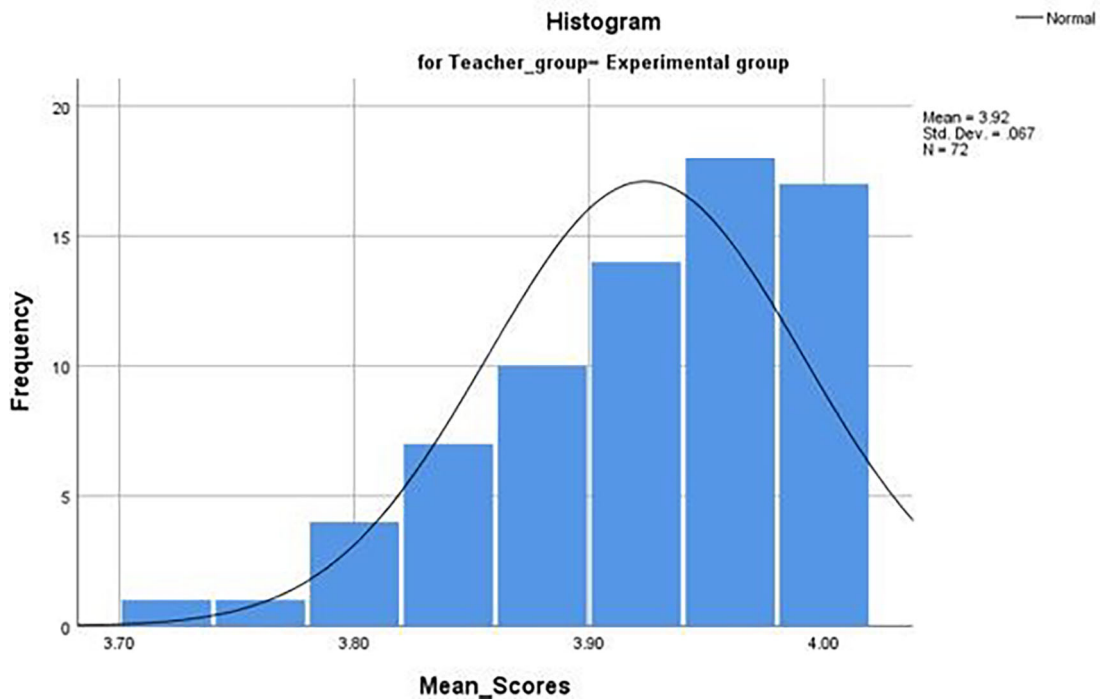


Figure 1. Score distribution in the experimental group.

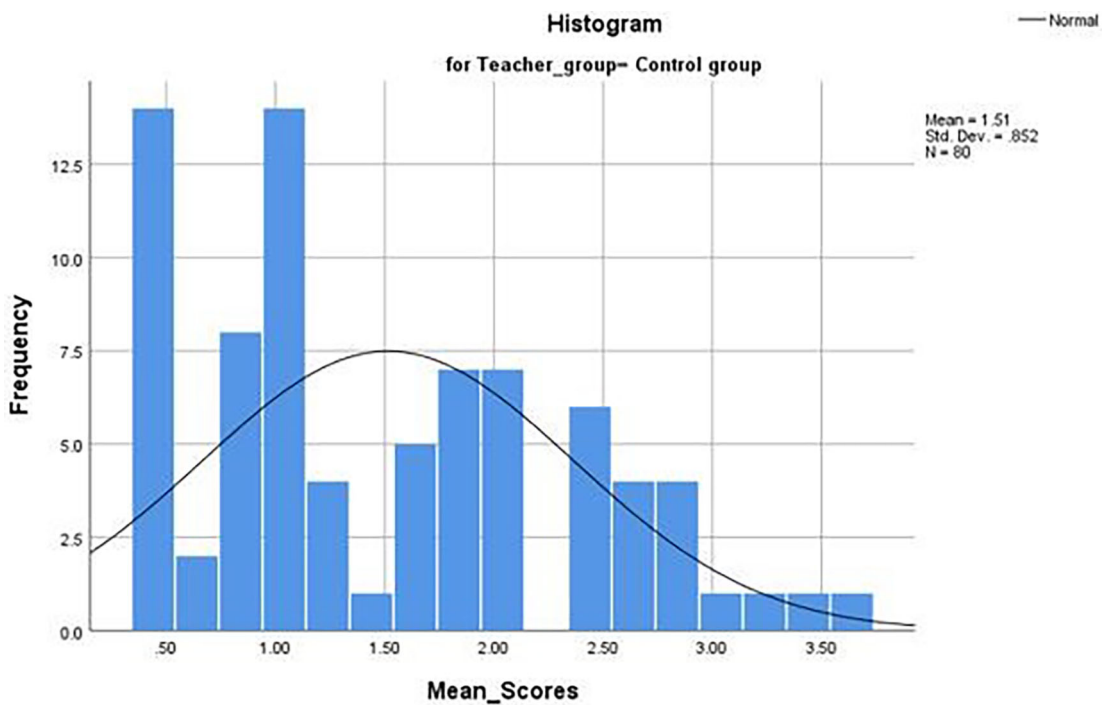


Figure 2. Score distribution in the control group.

Table 2 was drawn by computing means and STD between experimental and control groups. The 25 RTOP Statements are from three themes (lesson design and implementation, content, and classroom culture) and five sub-themes: (a) lesson design and implementation (1–5), (b) propositional knowledge (6–10), (c) procedural knowledge (11–15), (d) communicative interaction (16–20), and (e) student/teacher relationship (21–25). It can be seen that teachers who got

Table 2. Ugandan physics classroom practices.

		Items	Experimental group (No. of lessons observed=72)		Control group (No. of lessons observed=80)	
			Mean	STD	Mean	STD
Lesson design and implementation	1	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	3.78	0.42	1.16	1.05
	2	The lesson was designed to engage students as members of a learning community.	3.92	0.28	1.63	0.83
	3	In this lesson, student exploration preceded formal presentation.	3.86	0.35	1.31	1.07
	4	This lesson encouraged students to seek and value alternative modes of investigation or of problem-solving.	3.92	0.28	1.44	1.10
	5	The focus and direction of the lesson were often determined by ideas originating from students.	3.90	0.30	1.30	1.15
Content	6	The lesson involved fundamental concepts of the subject.	3.92	0.28	3.16	0.37
	7	The lesson promoted a strongly coherent conceptual understanding.	3.92	0.28	1.48	0.99
	8	The teacher had a solid grasp of the subject matter content inherent in the lesson.	3.96	0.20	2.43	0.84
	9	Elements of abstraction (i.e., symbolic representations and theory building) were encouraged when it was important to do so.	3.94	0.23	1.55	0.81
	10	Connections with other content disciplines and/or real-world phenomena were explored and valued.	3.89	0.32	1.19	1.09
Procedural knowledge	11	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	3.94	0.23	1.34	1.11
	12	Students made predictions, estimations and/or hypotheses and devised testing methods.	3.97	0.17	1.43	1.09
	13	Students were actively engaged in thought-provoking activities that often involved the critical assessment of procedures.	3.92	0.28	1.36	1.01
	14	Students were reflective about their learning.	3.97	0.17	1.63	0.80
	15	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	3.92	0.28	1.43	1.04

Table 2. *Continued*

		Items	Experimental group (No. of lessons observed=72)		Control group (No. of lessons observed=80)	
			Mean	STD	Mean	STD
Classroom culture	Communicative interactions	16	3.96	0.20	1.28	1.04
		17	3.99	0.12	1.54	0.76
		18	3.96	0.20	1.20	1.04
		19	3.94	0.23	1.38	1.04
		20	3.94	0.23	1.59	0.77
	Student/ Teacher Relationships	21	3.90	0.30	1.63	0.85
		22	3.97	0.17	1.41	1.09
		23	3.92	0.28	1.39	1.01
		24	3.92	0.28	1.33	1.03
		25	3.88	0.33	1.34	1.05

training in PBL reformed their teaching in the 3.78 and 3.97 range, while those that did not get training in PBL (control group) lowly reformed their teaching. Only two RTOP items among the control group got an average score (>2) and the rest of the scores were below 2. These are item-6 (the lesson involved fundamental concepts of the subject), which scored 3.16, and item-8 (the teacher had a solid grasp of the subject matter content inherent in the lesson), which scored 2.43 out of 4.

Figure 3 displays mean scores for each of the three themes. Each group performed similarly in Lesson design and implementation (items 1–5), Content (6–15), and Classroom culture (16–25), where the experimental group outperformed the control group.

Figure 4 displays mean scores for each of the five sub-themes, and each of the experimental and control groups show a similar performance. For instance, Lesson design and implementation (statements 1–5), propositional knowledge (6–10), procedural knowledge (11–15), communicative interaction (6–10), and student/teacher relationship (21–25) scored each between 3.5 and four. Likewise, the control group scored between 1 and 1.5, except for propositional knowledge.

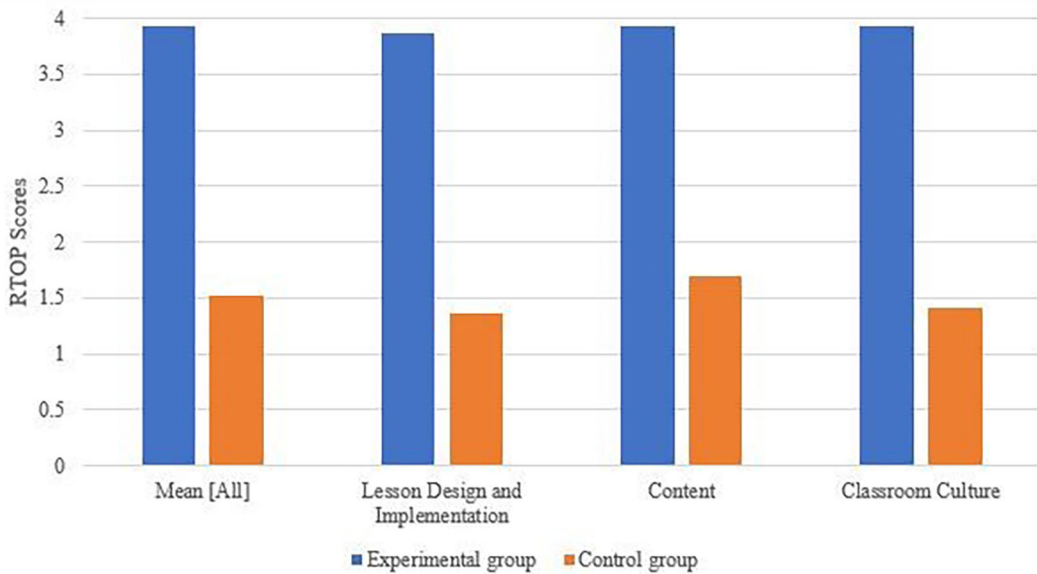


Figure 3. Theme analysis.

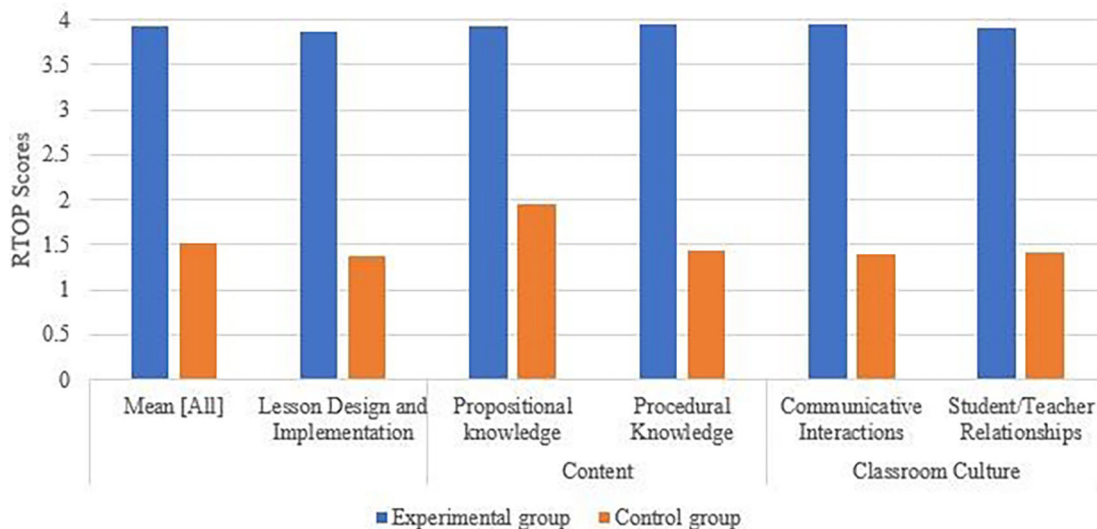


Figure 4. Sub-themes analysis.

Table 3. Descriptive and inferential statistics from Mann-Whitney U Test.

		N	Mean rank	Sum of ranks	Mann-Whitney U Test	p-value
Teaching intervention	Experimental	72	116.50	8388.00	0.000	0.000
	Control	80	40.50	3240.00		
Solomon's groups	Both pre- and post-test	88	87.19	7672.50	1875.50	0.000
	Only post-test	64	61.80	3955.50		
Sex	Male	112	71.80	8042.00	1714.00	0.027
	Female	40	89.65	3586.00		
School ownership	Government	56	77.24	4325.50	2646.50	0.874
	Private	96	76.07	7302.50		

Using Independent-Samples Mann-Whitney U Test, it was found that the distribution of mean scores was not the same across categories of teaching interventions (Table 3). Thus, a classroom that was taught with PBL showed a good teaching and learning practices than that taught with the traditional method. The same test showed that the group of students who did both pre-and post-test statistically performed significantly ($p < 0.001$) more than those who only performed post-test.

Using Independent-Samples Mann-Whitney U Test, a statistically significant difference ($p < 0.05$) between men and women teachers' classroom practices in favor of female teachers was found. However, the same test showed that the distribution of mean scores was the same across categories of school ownership (Government *versus* Private schools).

Discussion

The discussion of the results has been presented in relation to the research questions.

Is there a statistically significant difference in physics classroom practices among teachers who use Problem-Based Learning instruction and those employing Traditional methods?

In this study, a problem-based learning lesson was compared to a traditional instruction method (TIM) lesson using observation tools. PBL showed a statistically significant reformed physics teaching compared to TIM. Several studies have used observation tools to document classroom practices. For instance, *MacIsaac et al. (2001)* used reformed teaching as a catalyst for self-reflective change in secondary science teaching and found that it possesses a degree of credibility to document teaching and learning activities in a reformed form. RTOP requires a radically new type of teaching, in which the teacher has a radically new role. This is a complete transition from the traditional culture of physics lessons (*MacIsaac et al., 2001*). The renewed teaching appears quite different from traditional physics courses since the class is no longer focused on the teacher. Our study showed that most RTOP items scored more than 2 out of 4 scores in the class taught with PBL. Thus, this class achieved reformed teaching of mechanical waves because practices occurring in the classroom achieved more than 50% scores (*MacIsaac et al., 2001*; *Ndihokubwayo et al., 2020a*).

In this study, themes and subthemes scored similarly. This was different from other studies. For instance, *Ndihokubwayo et al. (2020a)* observed the implementation of competence-based learning in Rwandan physics classrooms and found varying scores across the themes of RTOP. They got 48% for content (procedural knowledge) and 60% for classroom culture (student-teacher relationships). Thus, the uniqueness of our findings is that PBL instruction showed the utmost support to improve students' and teachers' activities toward active and reformed learning. However, items 6 and 8 showed a good performance even for the traditional class. This was because these items are related to propositional knowledge that any teacher possesses despite the methods he may be using. This is content knowledge learned from school. For instance, the "lesson involved fundamental concepts of the subject" shows that any teacher in PBL or TIM class would possess such fundamental concepts of the subject. Likewise, the "teacher had a solid grasp of the subject matter content inherent in the lesson" shows any teacher, despite the teaching intervention, would be able to grasp such subject matter content knowledge.

In relation to the findings of *Amrein-beardsley and Popp's (2012)*, analysis of the performance of subthemes in our study indicated that majority of the participants were previously involved in some behaviors as seen in the classroom culture and pedagogy subscales. What was difficult was how to involve learners in more demanding and rigorous activities and methods. Responses from the survey administered by *Amrein-beardsley and Popp's (2012)* indicated that many

participants found it difficult to incorporate elements thought to be for only science or math classes, and specifically, those found to be difficulty to transfer to content specific to teacher education. Their study findings showed that use of classroom observations maybe a good guide not only for teachers to reflect on their teaching practices but also for observes to learn from others especially from more successful educators (Zaare, 2013). If a class is observed, the teacher may be enabled to clearly describe their instructional practices, assess inequalities that may exist among students, and also enhance classroom instruction. Generally, the teacher whose class in observed gains in-depth understanding of the theoretical knowledge as well as the practical choices of what, how, and what extent to use that knowledge in the classroom (Zaare, 2013).

The fact that teachers in PBL class showed a good reform in lesson preparation is that they were trained and were given the opportunity to prepare lessons based on PBL instruction. It is important to plan for lessons before teaching. Various authors concur that lesson planning reflects what the classroom would look like (Ndiokubwayo *et al.*, 2022, 2020b; Nyirahagenimana *et al.*, 2022). Teachers mastered the content as those in TIM class; however, they outperformed them in procedural knowledge. This is related to pedagogical knowledge that an effective teacher possesses. Effective teaching approaches and active learning strategies such as PBL took these teachers to a good level of reformed teaching than those using traditional and passive methods. This shows that if Uganda's educational policymakers would let teachers in high school implement a competency-based curriculum (CBC) with an effective pedagogical approach, a good atmosphere would be created in those classrooms.

In the PBL class, the classroom culture that was both communicative interaction and student or teacher relationships was more observed than in the TIM class. High scores on the RTOP call for student cooperative learning via extended dialogue where by it is the teachers' role to choose those activities which can facilitate dialogue, and be able to support, guide, and reward students' talk (MacIsaac & Falconer, 2002). MacIsaac and Falconer (2002) highlight that in teaching physics, there is no "golden road". This implies that on the side of physics teachers, RTOP emphasizes the importance of proper preparation, knowledge, and professional development.

Do factors such as exposure to pretest, teachers' sex, and school type influence physics classroom practices?

The pre-test effect improved the data, and classrooms that performed both pre- and post-test performed better than those that sat for only post-test. In fact, the use of Solomon's four-group design would show these controversies. Analyzing groups that both performed pre-test before intervention and those that only performed post-test remove the effect of pre-test to visualize the effect of teaching intervention. However, since this study is a follow-up of other studies from the first author's large doctoral research project, the observation of classroom practices did not aim to document performance and attitude or conceptual understanding (these concepts are already published: Kanyesigye, *et al.* (2022a, 2022d). The students in a group that performed a pre-test would perform better because they are alerted that they are equipped with a certain intervention, then follow all provided and scheduled activities carefully. However, students with only post-test know nothing until they realize that they perform post-test on activities already done.

Sex had an effect in favor of women teachers. The fact that female teachers performed more than their counterparts was a surprising authentic finding in this study since almost no available studies have investigated performance due to gender among teachers' classroom practices. In a similar study that investigated the performance among pre-service teachers, females showed a better performance than their male counterparts after having been taught with the lecture and lab methods; however, this was the opposite after having been taught utilizing the animation method (Mukagihana *et al.*, 2021). A similar observation did not affect when secondary physics teachers did not visualize different teaching practices (Ndiokubwayo *et al.*, 2020b). Despite the difference that occurred in teachers' classroom practices; however, no effect of teaching intervention was found in public or private schools. A similar outcome was found during learning optics with physical educational technology (PhET) simulations and videos (Ndiokubwayo *et al.*, 2020b; Uwamahoro *et al.*, 2021). This is a good practice because it shows a good level of Ugandan schools since there is a claim of inequality of schools' quality in various countries.

Limitations of the study

This study was limited to schools within Mitooma district which is a rural district located in southwestern Uganda with all secondary schools being both day and boarding. Further studies could be extended to other areas to include those schools that are purely boarding.

Generalizability of findings

The study was conducted in such a way that all grade 13 physics students existing in a particular school participated as cohorts. These students originate from different areas within the country. More so, recording of visual observations was

not directly announced to participants to allow them operate naturally. The observed teachers were both men and women who had professionally trained from different teacher-education institutions and are mandated to serve all over the country. These identified characteristics are believed to be shared by even other students and teachers that were not part of this study. Thus, to a certain extent, the data collected is generalizable.

Conclusion

We measured the teaching–learning practices due to the use of problem-based learning alongside the traditional instructional method among selected Ugandan physics classrooms. We trained teachers on how to use PBL in teaching and learning practices of mechanical waves and observed 152 classrooms. Teachers trained in PBL implemented the PBL instruction in experimental classrooms while teachers untrained in PBL implemented TIM in control classrooms. It was found that teachers who were trained in the use of PBL taught well compared to their counterparts (teachers untrained in PBL). Women teachers showed a statistically significant difference compared to their male teachers in reformed teaching of physics, while no significance was found between government and private schools. We recommended teachers use PBL in high schools in Uganda, policymakers train teachers in its implementations, and researchers investigate its effect on other topics and subjects with RTOP or other standard observation protocols.

Studies related to this current study

The current study is a portion of the corresponding author’s doctoral research project. There are other studies by the authors related to this study that may overlap in the methods or data. These are:

Published:

Kanyesigye, S. T., & Kemeza, I. (2021). Effect of Problem-Based Learning Instruction on Secondary School Physics Students in Understanding of Electromagnetic Waves. *Voice of Research*, 10(1), 1–17. http://www.voiceofresearch.org/Doc/Jun-2021/Jun-2021_1.pdf

Kanyesigye, S. T., Uwamahoro, J., & Kemeza, I. (2022a). Difficulties in understanding mechanical waves: Remediated by problem-based instruction. *Physical Review Physics Education Research*. <https://doi.org/10.1103/PhysRevPhysEduRes.18.010140>

Kanyesigye, T. S., Uwamahoro, J., & Kemeza, I. (2022b). Data collected to measure the impact of problem-based learning and document physics classroom practices among Ugandan secondary schools. *Data in Brief*, 44(108534 Contents), 1–9. <https://doi.org/10.1016/j.dib.2022.108534>

Kanyesigye, S. T., Uwamahoro, J., & Kemeza, I. (2022c). The effect of Professional Training on In-service Secondary School Physics Teachers’ Motivation to Use Problem-Based Learning. *International Journal of Learning, Teaching and Educational Research (IJLTER)*. <https://doi.org/10.26803/ijlter.21.8.16>

Kanyesigye S, Uwamahoro J and Kemeza I. (2022d). Effect of problem-based learning on students’ attitude towards learning physics: a cohort study [version 1; peer review: awaiting peer review]. *F1000Research* 2022d, 11:1240 <https://f1000research.com/articles/11-1240/v1>

Under review (at the time of publication):

Kanyesigye, S. T., Uwamahoro, J., & Kemeza, I. (2022e). The Impact of Problem-Based Learning on Students’ Achievement in Mechanical Waves in Secondary Schools. *Research in Science Education (RISE)*.

Data availability

We have previously published a data article in Data in Brief (Kanyesigye *et al.*, 2022b; 2022f) and full descriptions of the data can be found in this study.

Underlying data

Mendeley Data: Data for measuring impact of problem-based learning during learning mechanical waves: MWCS, VASS, RTOP. <https://doi.org/10.17632/rdtcgstmps.3> (Kanyesigye, *et al.*, 2022f).

This project contains the following underlying data:

- Reformed teaching observation classroom practices in Ugandan Secondary Form 6 [Feb-Apr 2021].xlsx (Raw data for the study)

Extended data

Mendeley Data: Data for measuring impact of problem-based learning during learning mechanical waves: MWCS, VASS, RTOP. <https://doi.org/10.17632/rdtcgstmps.3> (Kanyesigye, *et al.*, 2022f).

This project contains the following extended data:

- Ugandan Secondary Form 6 Students Views About Sciences Survey [Feb-Apr 2021].xlsx (Data set on students' attitude towards waves)
- Ugandan Secondary Form 6 Responses on Mechanical Wave Conceptual Survey [Feb-Apr 2021].xlsx (Data set on students' understanding of waves)

Mendeley Data: Teacher Training in Implementing Problem-Based Learning. <https://doi.org/10.17632/b28d3p7kf8.1> (Kanyesigye, 2022).

This project contains the following extended data.

- Training of Teachers in Problem-Based Learning.pptx (Literature on how to implement Problem-Based Learning in a real classroom)

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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