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Lesson observation tool for project-based learning: a useful tool for learner-centered pedagogy enhancement

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Introduction: The CBC has been implemented in pre-primary through secondary schools in Rwanda. However, a gap was found in assessing the implementation of the CBC since there is no documentation to fulfill the need.
Methodology: This study is a product of a validated and reliable Lesson Observation Tool for Project-based Learning (LOTPBL), designed to fill the gap in monitoring and assessing the implementation of a competence-based curriculum within a project-based learning (PjBL) framework in Rwanda. The tool was piloted to check for its construct. The tool was checked for reliability. The calculated Kappa coefficient was 0.8, indicating that the tool is suitable for use. The tool was used while observing one teacher during 60 lessons (30 lessons before and 30 after the intervention).
Results: The tool was found worthy to be used during lesson observations about project-based learning instructions. The analysis of the collected sample data revealed an improvement in the teacher employing key observations of PjBL during instructions (p-value = 0.0096; $p < 0.05$). The computed t-statistic of −3.38 with a two-tailed p-value of 0.0096 ($p < 0.05$) confirms that this improvement is statistically significant.
Discussion: These results indicate a notable enhancement in the implementation of strategies such as project initiation, student-centered learning, collaboration, and authentic assessment during instructions. The LOTPBL holds significant potential for supporting the global shift toward competency-based and active learning methodologies through project-based learning.

KEYWORDS

competence-based curriculum, learner-centered approach, mathematics, LOTPBL, project-based learning

1 Introduction

The Ministry of Education (MINEDUC) in Rwanda, through the Rwanda Basic Education Board (REB), has revised its curriculum to shift from a knowledge-based curriculum (KBC) to a competence-based curriculum (CBC) in 2015. The curriculum was revised with a national aspiration to develop students' competencies, including knowledge, skills, attitudes, and values, to enable them to succeed in an era of rapid technological growth and socio-economic development (Ndihokubwayo et al., 2020; Rwanda Basic Education Board [REB], 2015). In this regard, the CBC was designed to promote a learner-centered approach and replace teacher-centered and passive learning. Thus, learners should participate in their learning, construct knowledge themselves, and develop new knowledge. This act allows them to conceive learned knowledge and transform it into skillful output and value its usefulness in their daily life. (REB, 2015). Since 2016, the CBC has been implemented in pre-primary through secondary schools in Rwanda. However, a gap was found in assessing the implementation of the CBC since there is no documentation to fulfill the need (Ndihokubwayo et al., 2021). A standard classroom observation tool is needed to provide reliable data about the extent to which teachers apply active teaching methods as a result of an effective implementation of CBC.

REB in partnership with various developmental partners (DPs) such as Japan International.

Cooperation Agency (JICA), Building Learning Foundation (BLF), British Council, Well Spring, Educate!, and Inspire-Educate-Empower (IEE-Rwanda), among others, has continuously trained teachers to implement CBC across the country. However, a gap was found in implementing the curriculum since the traditional teaching approach still dominates the class (Nsengimana Mugabo et al., 2021; Uwizeyimana et al., 2018). In the study conducted by Ndihokubwayo et al. (2021) about the implementation of CBC, it was found that the CBC implementation faces challenges such as the lack of budget for organizing training and teachers during Continuous Professional development (CPD) and some teachers who resist CBC approaches. However, Ndihokubwayo et al. (2020) later assessed the implementation of CBC and found that learner-centered was improved over the past 5 years. The researcher employed a qualitative survey for 29 sector education officers (SEOs) to learn about the CBC implementation and monitoring experience. The emphasis was on investigating the collaboration between SEOs, district officials, school leaders, and teachers. Yet, no classroom observation tool was in place to be used specifically assessing the teacher's adoption of learner-centered teaching approaches through PjBL. Therefore, there is a need to assess the extent to which teachers use different teaching methods to implement some active learning methods such as project-based learning (PjBL).

PjBL-based instructions are distinct from other learning models because they focus on students' ideas, particularly in developing their picture of working on relevant topics based on students' interests and experiences. During PJBL, the teacher's job is to mentor and counsel students rather than oversee and regulate their work (Serin, 2019). PjBL encourages students to be independent while managing their tasks and study time. During PjBL, students use effective strategies, seeking answers to questions using cognitive problem-solving approaches (Fisher et al., 2020; Serin, 2019). Through PjBL, students collaborate in groups to solve complex issues grounded in the curriculum. Students choose what activities to engage in and how to tackle a challenge. In this context, students collect data from many sources, synthesize it, examine it, and draw knowledge from it (Han et al., 2016). Indeed, the studies by Han et al. (2016) and Wakumire et al. (2022) found that PjBL enhances active knowledge acquisition and skills development. Scholars like Twahirwa et al. (2021) and Gasana et al. (2023) conducted studies on the effectiveness of PjBL and claimed that PjBL promotes active learning, knowledge acquisition, creativity, collaboration, and critical thinking among students. There is a need to assess the teachers' teaching practices in incorporating PjBL to teach different subjects using adequate lesson observation tools. Teaching requires ongoing multiple decisions and responsive actions based on the observed teaching and learning processes. Performing essential teaching aspects can be measured using well-designed observation tools (Stearns et al., 2012). To my knowledge, no standard tool was developed and used to assess the extent to which the PjBL was employed during instructions. Thus, a Lesson Observation Tool for Project-based Learning (LOTPBL) was developed to assess the extent to which the teacher apply PjBL key elements (see Appendix).

Scholars have developed lesson observations tool to assess whether learning is active or passive. For instance, Ndihokubwayo et al. (2020) developed a Reformed Teaching Observation Protocol (RTOP) and used it to assess the implementation of CBC to teach science subjects in secondary schools in Rwanda. The emphasis was put on classroom dynamics, such as learners' active participation. In addition, an Observation and Analytic Protocol (OAP) was developed (Sawada et al., 2002). The tool is made of a 25-KO to assess whether the instruction is standards-based, inquiry-oriented, and student-centered. Furthermore, Hora (2015) developed an Observation Protocol Teaching Dimensions Observation Protocol (TDOP). The TDOP is made of codes, revealing active learning modalities such as being active (students answering questions), being constructive (students asking questions and students doing creative tasks), and being interactive (students working with peers). The reviewed tools have limitations in focusing on students' dynamics. This gap leaves a need for developing a tool suitable to assess the extent to which students are engaged when an active teaching method such as PjBL was employed.

The study was based on the constructivism learning theory (Bada and Olusegun, 2015). Constructivism is a learning theory found in psychology that explains how people learn to acquire knowledge. The theory suggests that individuals construct knowledge from their experiences. Through this theory, students conduct investigations and perform meaningful tasks related to the learners' daily lives. In addition, students make conjectures and prove hypotheses through hands-on activities (Osman and Kriek, 2021). The PjBL key observations of LOTPBL are expected to yield data about the extent to which students are engaged through PjBL to acquire competencies such as knowledge, skills, attitudes, and values.

The study was also guided by the Theory of Change (ToC; Reinholz and Andrews, 2020). The ToC is a wide-ranging comprehension of how and why a desired change should happen in a particular context. This theory is useful in understanding teachers' classroom practices and provides a framework for considering how teachers can be supported to improve their teaching practices. Through the teaching experiment, the participant teacher was given a one-day training and was guided by the researcher to effectively apply PjBL. The LOTPBL was used to assess the teachers' effectiveness in applying PjBL principles while teaching Mathematics.

2 Methodology

2.1 Validity testing

The face and content validity of the tool were checked by expert review. Through the process, the tool was shared with different individuals' experts and experienced in mathematics and science education from primary through higher institutions. The reviewers include two experts and lecturers in higher learning institutions, two scholars, and PhD graduates in Physics and Biology.

Education, 2 MEd students and experienced teachers in teaching Physics and Chemistry, and two experienced tutors from 2 TTC helping pre-service teachers in teaching practices. The development of the tool was motivated by the need to ensure that teachers include the necessary elements for PjBL-led lessons (Abidin et al., 2020). The tool was progressively improved through a series of modifications aimed at enhancing its face and content validity, culminating in the final version. The tool's development underwent three stages.

In the first stage, the tool started with the Name "A Lesson Observation Checklist" to be used as a checklist by education evaluators. The tool was composed of 17 KOs with "Yes" and "No" options. The tool was administered to a panel of reviewers (supervisors), who offered constructive feedback and recommendations to enhance its validity and applicability. For instance, KOs such as "The teacher gives students the freedom to work on the project and given activities," "The teacher provided feedback is clear, and constructive showing the specific improvement needed," "Students take responsibility of ownership," and "Students show curiosity to do more about the project," were removed since they were found ambiguous.

In the second stage, the tool was deeply modified. The tool's name was changed to "Classroom Observation Protocol for Project-Based Learning (COP^{2}BL). Some KOs were removed, and more KOs were added. KOs were deleted because they were irrelevant or repeating. The revised tool has 25 key observations with five options (not all, slightly well, moderately well, very well, extremely well). These scales were initially chosen to indicate at which level the key observation was performed by the teacher and/or students. The column for explanation was deleted. Two main parts; Teachers' behaviors and students' behaviors during instructions, were created. Components or themes were created based on related elements. Questions were changed into KOs. The word "Geometry" was changed into "Mathematics" to make the tool more general. The tool was subsequently redistributed to the reviewers for further evaluation and feedback.

In the third phase, the five options in phase two were changed into two options (occurred and not occurred options) since the reviewers emphasized that the main purpose of the tool is based on assessing if, during the lesson, the KO of PjBL occurred or not (Osman and Kriek, 2021). During this phase, 25 KOs were grouped under nine components. The KOs were also arranged into three main parts of the lesson (Introduction, lesson development, and conclusion; See Appendix). The construct validity was done through a pilot study. The results from the pilot study showed that the tool measures what its supposed to measure based on the theoretical constructs of PjBL.

2.2 Reliability testing

A training of about 2 h was required for three raters before the use. During the training, raters discussed the tool's nine components and 25 key observations. This increases the understanding of the tool. Through the discussion, trainees showed an understanding of the tool. However, that was not enough to confirm that raters can use the tool to collect reliable data. To calculate the inter-rater reliability (IRR), four raters observed three videos corresponding to three lessons recorded during the pilot study. The videos (recorded lessons) were observed by four raters in three steps while finding the inter-rater reliability. We used MS Excel 2016 to compute the agreement between every two raters. Each rater score "1" if an activity occurred or not occurred. Either score was applied for each of the 25 key observations. After, we computed the difference between scores from two raters for each LOTPBL. We counted the number of agreements and disagreements for each rater. The IRR was calculated by pairing raters' scores as follows: 1 and 2, 1 and 3, 1 and 4, 2 and 3, 2 and 4, and 3 and 4 as shown in Figure 1. The percentage of agreement between the two raters was calculated at 67%. This percentage is low, indicating that raters do not agree with many key observations. For instance, there were disparities in key observations such as "The teacher acts as a facilitator rather than a direct instructor," "Students show critical and creative thinking to address the project challenges.," "Students summarize the lesson and provide key takeaway." and "The teacher provides feedback that helps students improve their work." These KOs were deeply discussed before observing the second video.

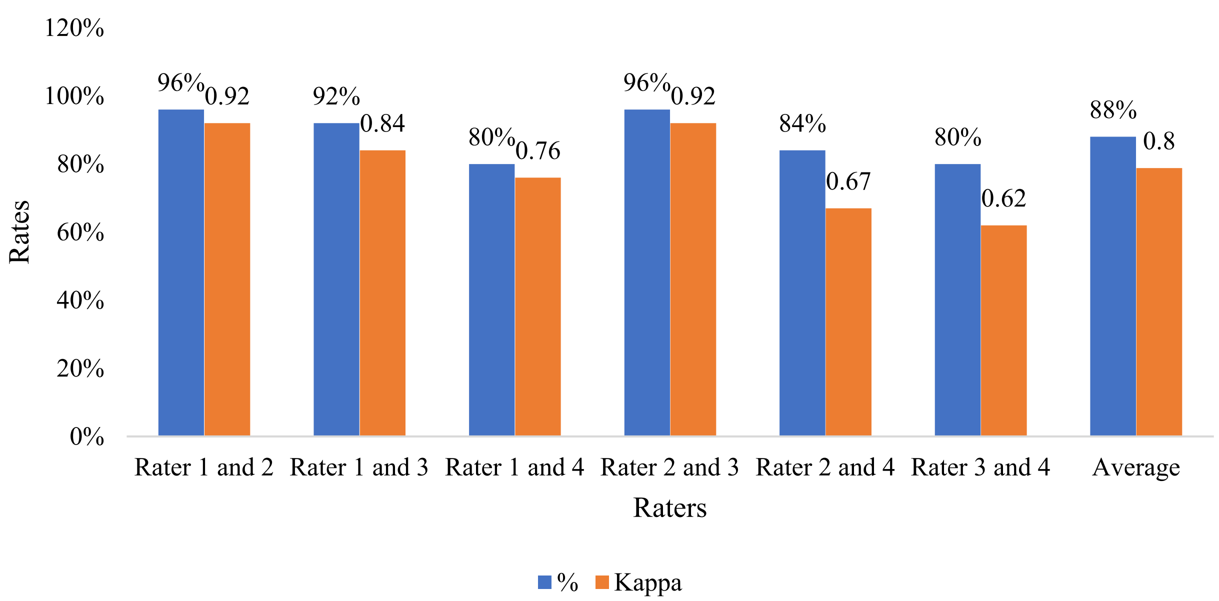

FIGURE 1
Inter-rater reliability. Source: Primary data (May 2024).

After adjusting the tool, raters observed the second video and restarted scoring. We calculated the Cohen Kappa coefficient to avoid the rating by chance. We used SPSS version 25.0 in the following steps: [Analyze > Descriptive Statistics >Crosstabs>Kappa statistics], and then hit Ok. Results from three raters were transcribed, and SPSS software was used to calculate the Inter-rater reliability (IRR) generated by the Cohen Kappa coefficient. The IRR between raters 1 and 2, 1 and 3, 1 and 4, 2 and 3, 2 and 4, and 3 and 4 was 60, 64, 68, 68, 72, and 64% with an average of 66%. This value was moderate reliability, implying that the tool needs to be improved and understood more. A discussion followed to clarify some key observations. For instance, a high disagreement was found again in key observation "Students summarize the lesson and provide key takeaway." This KO was more discussed and other discussions about the previously observed video were done. The third video was observed and the IRR was calculated. The calculated IRR was 88%, with a Cohen Kappa coefficient of 0.8. McHugh argues that the strong level of agreement ranges from 0.80 to 0.90 (McHugh, 2012). This is a high reliability. These results indicate that the LOTPBL is suitable to be used during lesson observations to collect data about the extent to which PjBL is applied during instructions.

2.3 Ethical approval

Before commencing the research, researchers obtained a research ethical clearance letter issued on 29th March 2024 by the UR-CE Research Screening and Ethics Clearance Committee (RSEC-C) through the Research and Innovation Unit. The reference number of the letter is DRI-CE/031(a)/EN/gi/2024. In addition, a recommendation letter was provided by RSEC-C and used to request permission to conduct a study within the district. An authorization letter was presented to the school Headteacher and the participant Teacher. The tool was piloted before its use. Participants were explained the purpose of the study and signed informed consent forms before the study.

2.4 Intervention

This tool was used during data collection of the main author pursuing PhD study. The tool helped the author to measure the teacher's teaching effectiveness in applying PjBL while teaching mathematics to P5 students. The author used the teaching of teaching experiment as an intervention to enhance the teacher's effectiveness in applying PjBL in teaching mathematics.

During data collection, the author observed a participant teaching 60 mathematics lessons taught for P5 students purposively selected from one public school located in Nyamasheke district, Western Province of Rwanda. Two phases were needed to collect data. In the first phase, 30 lessons were observed during the third term of the academic year 2023/2024. Each lesson had a period of 40 min. During the observation, the researcher was actively involved and worked collaboratively with the participating teacher to plan for lessons. The content taught was linked to two learning units from the P5 Mathematics curriculum. These units are Unit 12: "Drawing and constructing of angles," and Unit 13: "Interpreting and constructing scale drawings." For the second phase, 30 lessons were observed during the second term of the academic year 2024/2025. During this phase, the teacher taught independently Unit 8: "Solving problems involving time intervals" for P5 students. The taught units were considered since they were on the teacher's scheme of work which corresponds to the period of intervention and data collection.

During the intervention, the researcher worked closely with the teacher through classroom-based research or teaching experiment framework. The teaching experiment involves supporting the participant teacher in improving the teaching practices. The framework involves five cyclic phases. These are Planning, Implementation, Observation, Reflection, and Revision (Steffe and Thompson, 2000). The collaborative feature of the teaching experiment model will potentially enrich the research process outcomes as it also contributes to the professional development of teachers through an enhanced teaching practice.

The teaching experiment model has five cyclic phases, including planning, implementation, observation, reflection, and revision. The cyclical process ensures continuous improvement in teachers' effectiveness.

3 The LOTPBL use

3.1 The LOTPBL format

The tool is made with three main sections. The first part is Demographic information. For this part, the user fills in information such as school name, subject being taught, unit, lesson, class, number of students, name of a project, teacher's name, lesson starts at, lesson ends at, and date; The second part is made of 25 Key observations (KOs). During observation, the user (observer) scores "1" in the cell under "Occurred" or "Not occurred" options for each key observation. For a more conceded analysis, 25 KOs were merged under 9 components (Project initiation, Student-centered learning, Inquiry and research, Collaboration, Application of knowledge and skills, Creativity and innovation, Use of instructional materials, Reflection and feedback, and Authentic assessment), and the components are under three main parts of the lesson (Introduction, development, and conclusion). The third part is General comments. In this part, the user provides a general insight about the observed lesson.

3.2 Data recording and analysis

To record data, key observations or KOs are on a row while lessons are on a column (See Figure 2). Maximum scores and percentages can be calculated for each lesson (horizontal analysis). The rationale behind utilizing horizontal analysis is to find the frequency of occurrence and non-occurrence for each key observation (statement) throughout the observed lesson in percentages (%). Finding the averaged scores (%) shows the extent to which the observed lessons were based on PjBL. If the calculated average percentage of occurrence is less than 50%, then the lessons were less likely to be based on PjBL key observations. The teaching was teacher-centered or passive. If the calculated percentage of occurrence is greater than 50%, then the observed lesson was in general more likely to be based on PjBL key observations. The teaching was active or learner-centered.

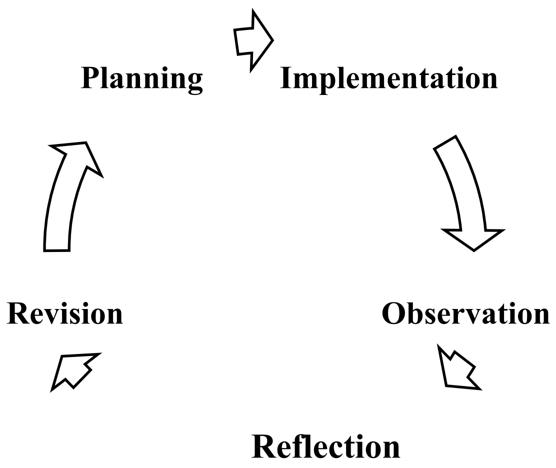

FIGURE 2
The teaching experiment model (Steffe and Thompson, 2000).

The vertical analysis is also conducted to calculate the sum, %, and average of the occurrence or non-occurrence for all 25 key observations. If the calculated percentage is greater than 50%, it means the KO has dominated throughout the observed lessons. If the calculated is less than 50%, it means that the KO was less dominant throughout the observed lessons.

Figure 3 illustrates a sample of 10 observed lessons taking only 7 KOs. Scores were taken randomly. Taking an example for Lesson 1, the occurrences and non-occurrences have max scores of 7 and 3 corresponding to 70 and 30%, respectively. The average in % of occurrence and non-occurrence for all 10 observed lessons is 52 and 48%, respectively. The analysis of the KO by KO of occurrence and non-occurrence yields the sum, %, and average scores. For instance, the KO number 1 (KO 1), has a sum of 9 and 1 scores, percentages of 90 and 10%, and the average of 0.9 and 1.0 scores, respectively.

4 Results and discussion

Thirty classroom observations were conducted using a LOTPBL to assess the extent to which the teacher adhered to 25 PjBL key observations. These scores were also calculated in percentages. The obtained results are presented in tables. Results were analyzed using descriptive frequencies and percentages. In addition, inferential statistics such as t-tests were calculated to compare means scores of applying PjBL before and after the intervention.

Emphasizing on "occurrence" option of KOs, an improvement was observed for many KOs. For instance, an improvement was found in certain KOs such as the teacher acting more as a facilitator and students increasingly using hands-on materials (both moved from 30 to 100%). The improvement can be attributed to the positive influence of the intervention (KO 5 and 17). The teacher followed the training offered and received clear guidance on implementing core project-based learning (PjBL) practices. The notable gains were also found in KOs related to student ownership, teamwork, and reflective project alignment (KOs 3, 4, and 8) with a move from 22 to 73%, from 28 to 93%, and from 27 to 78%, respectively. These findings indicate that the intervention helped foster a more participatory and project-aligned classroom environment.

However, the lack of improvement was identified in KOs tied to a drop in students using diverse information sources (KO 7), Students showing critical and creative thinking to address the project challenges (KO 14), and Students reflecting on their learning process, challenges, and improvements (KO 19) moved from 10 to 33%, from 12 to 40%, and 16 to 53%, respectively. It is suggested that these aspects were not sufficiently addressed or supported during the intervention. No improvement at all was observed for KO 18 regarding the student's use of online platforms or software during project implementation (0% both during and after intervention). One possible reason for this decline could be that the intervention emphasized surface-level engagement (e.g., facilitating activities or using hands-on materials) but did not sufficiently develop deeper learning strategies, such as research skills and structured reflection. Another factor might be limited time or resources during implementation, causing teachers to focus more on visible project tasks. These results highlight the need for further support in helping teachers embed inquiry-based learning and self-assessment routines into their daily teaching practices.

The general observation of the results presented in Figure 4 shows that in the first phase of observation, the participant teacher's adherence to PjBL key observations was fairly good, with an average moving from 21 to 70% during and after intervention, respectively. The intervention seems to have effectively emphasized student-centered methods and active learning strategies. These results show the teacher will shift from traditional instruction toward facilitation. The teacher encouraged student engagement in tangible, collaborative project activities.

For a deep analysis, 25 KOs were grouped under components, formulated based on PjBL key principles (Abidin et al., 2020). Thus, nine components were generated. The analysis was also conducted across nine components. These components are:

(i) Project initiation [1, 2, 3], (ii) Student-centered learning [4, 5], (iii) Inquiry and research [6, 7], (iv) Collaboration [8, 9, 10], (v) Application of knowledge and skills [11, 12], (vi) Creativity and innovation [13,14,15], (vii) Use of instructional materials [16,17,18], (viii) Reflection and feedback [19, 20], and (ix) Authentic Assessment [21, 22, 23, 24, 25]. The presented results in this section show the average occurrence of these components throughout the 30 observed lessons during and after the intervention.

Figure 5 reports the average of the teacher's adherence to PjBL lesson components. The results from the study show an increase in the teacher's adherence to 9 components expected to be considered in the lesson. A significant increase was observed in teachers initiating the project, the student-centered learning, collaboration, and the use of resources with an increase from 16 to 24, from 16 to 30, from 20 to 26, and from 14 to 30, respectively. The improvement in key components of project-based learning indicates the effectiveness of the intervention. The teacher's improvement in initiating the project suggests a clear instructional focus. The increase in use of instructional materials and collaborative learning indicates a move from passive learning to more autonomous and more engaged learning.

The inferential statistics t-test was used to compare score differences in teachers' abilities to cope with PjBL principles before and after the intervention. See Table 1.

The results from the t-test results analysis revealed a statistically significant improvement in teachers' skills to apply nine key

DATA PRESENTATION FROM THE LOTPBL

	#Key Observations	KO 1		KO 2		KO 3		KO 4		KO 5		KO 6		KO 7		SUM (Max=10)		%	
	Options	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred	Occurred	Not occurred
	Components	Project initiation						Students-centered learnining				Research and inquiry							
1	Lesson 1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	7	3	70	30
2	Lesson 2	1	0	1	0	1	0	0	1	1	0	0	1	0	1	4	6	40	60
3	Lesson 3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	7	3	70	30
4	Lesson 4	1	0	1	0	1	0	0	1	1	0	0	1	0	1	4	6	40	60
5	Lesson 5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	7	3	70	30
6	Lesson 6	0	1	1	0	1	0	0	1	1	0	1	0	1	0	5	5	50	50
7	Lesson 7	1	0	1	0	0	1	1	0	0	1	1	0	0	1	4	6	40	60
8	Lesson 8	1	0	0	1	1	0	0	1	1	0	0	1	1	0	4	6	40	60
9	Lesson 9	1	0	1	0	1	0	1	0	1	0	1	0	1	0	7	3	70	30
10	Lesson 10	1	0	1	0	0	1	0	1	1	0	0	1	0	1	3	7	30	70
	Sum	9.0	1.0	9.0	1.0	8.0	2.0	5.0	5.0	9.0	1.0	6.0	4.0	6.0	4.0	70	48		
	%	90	10	90	10	80	20	50	50	90	10	60	40	60	40				
	Average	0.9	0.1	0.9	0.1	0.8	0.2	0.5	0.5	0.9	0.1	0.6	0.4	0.6	0.4	5.2	4.8	52	48

FIGURE 3
The sample of excel spreadsheet data from the LOTPBL.

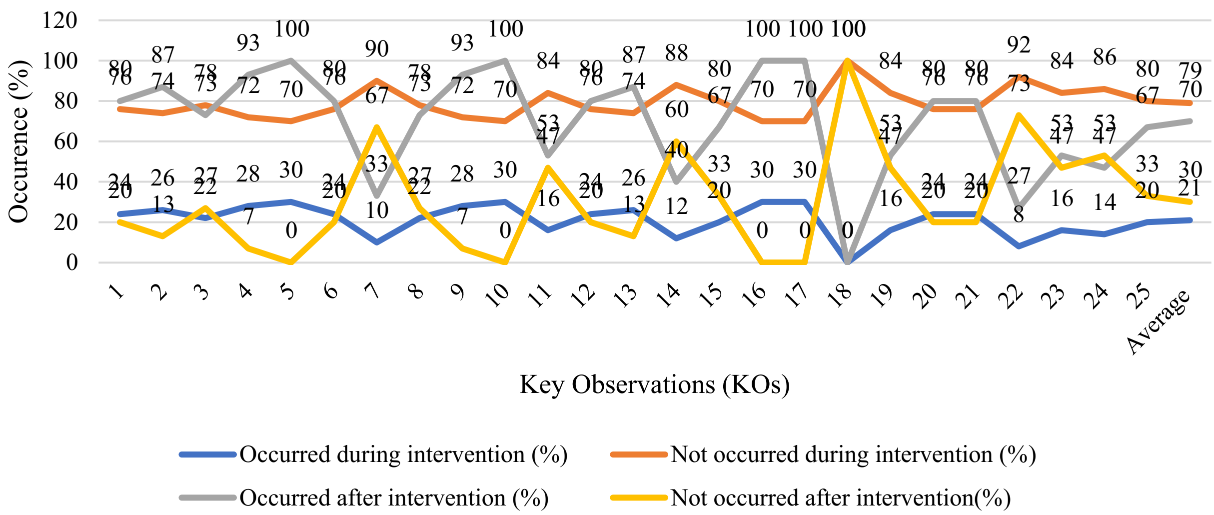

FIGURE 4
Occurrence of PjBL KOs during and after intervention.

components of project-based learning (PBL) after the intervention. The mean scores occurrence of PBL components increased from 54.8 to 75.6% before and after the intervention, respectively. These results indicate a notable enhancement in the implementation of strategies such as project initiation, student-centered learning, collaboration, and authentic assessment during instructions. The computed t-statistic of −3.38 with a two-tailed *p*-value of 0.0096 ($p < 0.05$) confirms that this improvement is statistically significant. However, a low Pearson correlation (0.0879) suggests a limited linear relationship between paired observations. The overall findings strongly suggest that the intervention had a positive effect on teacher's integration of PBL components during observed lessons.

The analysis was also conducted to see how individual lessons were taught across all 25 key observations during and after the intervention. The observed lessons are 60 (30 during and 30 after intervention). Figure 3 generates the number of the key observations adhered to out of 25 key observations.

Figure 6 shows 30 lessons observed across 25 key observations necessary for each lesson. The general observation is that observed key observations have increased after the intervention compared to observed key observations during the intervention. At least 7 out of 25 key observations were observed across the 30 lessons observed. The majority of key observations were observed for lessons 11, 18, 22, 26, 29, and 30, with 20 and 23, 15 and 22, 22 and 22, 15 and 22, 20 and 23, and 22 and 22 out of 25 key observations both during and after intervention, respectively. Increased from Lesson One to Lesson 30 during and after the intervention. The average of all observed key observations for all 30 observed lessons is 13 out of 25 during the intervention and 18 out of 25 after the intervention, respectively. The results indicate

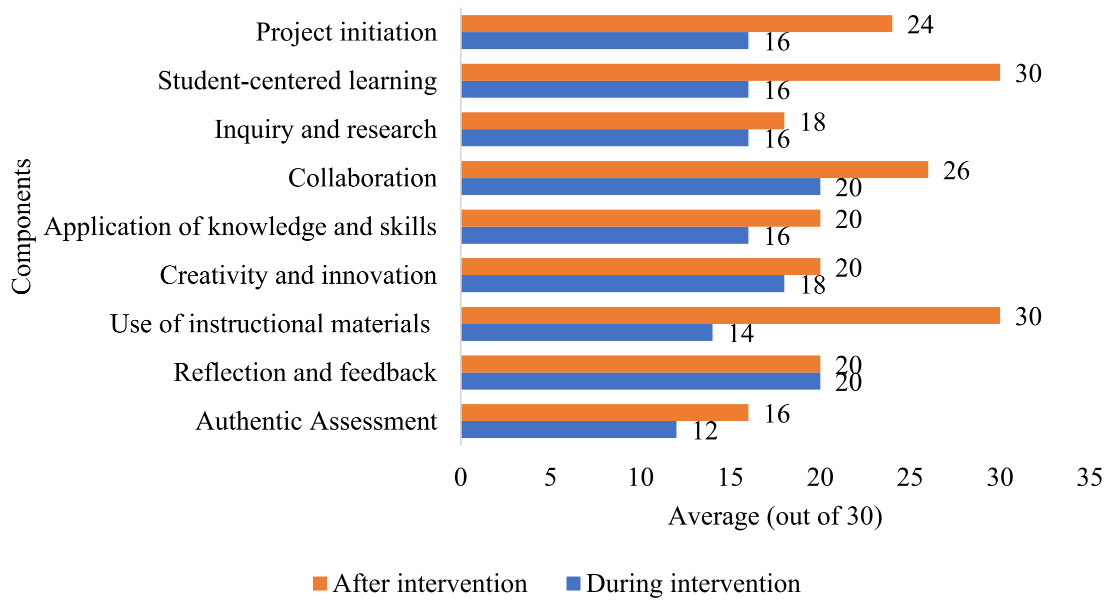

FIGURE 5
Results about learning environment based on 9 components of PjBL instructions.

TABLE 1 T-test statistical analysis results.

Test parameters	Before intervention	After intervention
Mean	54.8148	75.5556
Variance	75.3086	288.8889
Observations	9	9
Pearson Correlation	0.0879	
df	8	
t Stat	−3.3831	
P(T < =t) one-tail	0.0048	
t Critical one-tail	1.8595	
P(T < =t) two-tail	0.0096	
t Critical two-tail	2.3060	

a progressive improvement in incorporating project-based learning during and after the intervention. These results suggest that the intervention positively impacts the teacher's adherence to the PjBL framework.

The inferential statistics (t-test) was also calculated to compare the score mean difference in teachers delivering lessons before and after the intervention. See Table 2.

The t-test results from Table 2 indicate a statistically significant improvement in project-based learning (PBL) lessons after the intervention. The mean score increased from 44.89 to 61.56 before and after the intervention, respectively. The calculated t-statistic of −9.85 is far greater than the critical value (−2.0452) in absolute terms. The p-value is 0.0000 ($p < 0.05$), indicating that the difference in means is statistically significant. In addition, the high Pearson correlation (0.7463) between the paired scores suggests a strong positive relationship. The correlation indicates that the changes were consistently observed across participants. The overall intervention appears to have had a substantial and reliable positive impact on the quality or effectiveness of PjBL lessons.

With 25 key observations of the LOTPBL, it was found that the tool has the potential to determine whether the observed learning was either active or passive. These two teaching and learning aspects also inform the extent to which the CBC is being implemented. Similarly, different scholars have developed tools which can be used to assess learning instructions while implementing CBC curriculum. For instance, Smith et al. (2013) developed a Classroom Observation Protocol for Undergraduate STEM (COPUS). The tool comprises 25 codes that show instructors' and students' activities at intervals. With this tool was also found reliable to the extent students to which students are engaged. The tool provides data about whether the instruction was either learner-centered or teacher-centered. Similarly, Stearns et al. (2012) developed a Teacher Observation Instrument for PjBL Instruction. The tool is composed of KOs assessing how the teacher facilitates PjBL, students' participation, the availability and students' use of resources, assessment, and student engagement. The LOTPBL will be used to complement data provided by existing tools.

The majority of PjBL components were scored highly after the intervention. The increase may due to due to the continuous support provided by the researcher through teaching experiments, the teacher's interest in applying PjBL, and the use of instructional materials. Integrating project-based learning in mathematics education has brought significant attention to educational research globally since this teaching strategy strengthened students' problem-solving and critical-thinking skills (Zhang and Ma, 2023). It is the reason why Morrison et al. (2021) advocate for continuous professional development to enhance teachers' adoption of innovative teaching strategies. Through the LOTPL, mathematics teachers should change the way they teach and view it as anticipated by the Theory of Changed on which the study is based (Reinholz and Andrews, 2020). The results suggest that PjBL empowers teachers to improve their instructions for a more active learning environment.

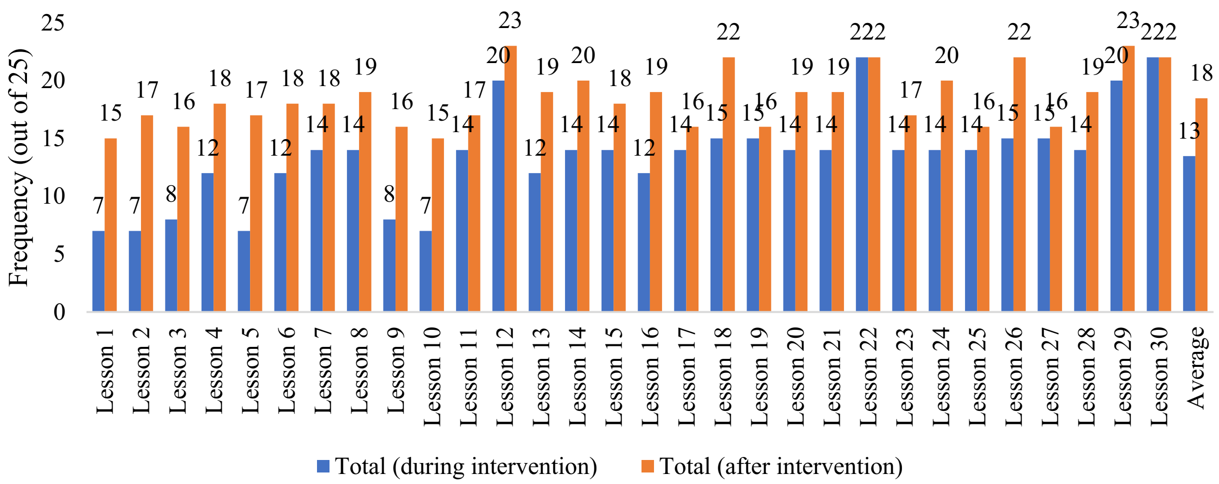

FIGURE 6
Observed lessons during and after the intervention.

TABLE 2 T-test statistical analysis results of delivered lessons.

Test parameters	During intervention	After intervention
Mean	44.8889	61.5556
Variance	183.7037	64.1635
Observations	30	30
Pearson Correlation	0.7463	
df	29.0000	
t Stat	−9.8538	
P(T < =t) one-tail	0.0000	
t Critical one-tail	1.6991	
P(T < =t) two-tail	0.0000	
t Critical two-tail	2.0452	

Teacher's perceptions during the interview explain why the teacher has improved the teaching practices over time. The teacher claimed that professional growth was enhanced. The teacher witnessed that mathematics could be applied beyond the classroom. The teacher discussed knowledge and skills gained during and after being supported to implement PjBL. The teacher argued that the support provided by the researcher enhanced the skills and ability to apply the new teaching approach, and became confident progressively. The participant's teacher argued, *"Before, I was not aware of PjBL. I could not understand how to teach mathematics lessons through project-based learning. Today, I understand all about PjBL. I am confident. I can now explain to the students how the lesson will be conducted through PjBL (Interview: 17th February 2025)."*

The strong interest in PjBL expressed by teachers informs positive insights indicating the teacher's awareness of the relevance of PjBL in enhancing students' understanding and skills development. Similarly, Palmer (2006) argued that when teachers are both interested in and confident about a teaching method, they are more likely to implement it effectively and consistently. These perceptions changed the participant teaching practices by giving students hands-on activities and activities involving students to apply concepts learned outside the classroom. Mathematics should be viewed as a tool used to solve different real-world problems.

The teacher further explained that the improvement in teaching practices was due to the provision of sufficient instructional materials. By using instructional materials, the students' conceptual understanding increased. The teacher argued: "*At the beginning, it was somehow difficult because we did not have watches to use during reading time. However, as we progressed, students understood the content because they were using watches. The lesson was generally easy to deliver (Interview: 17th February 2025).*" Before the intervention, the teacher used to come into class only with a book and pieces of chalk. Mathematics abstract concepts were explained without being applied in students' real context. The teacher observed that students who are directly involved in hands-on activities easily remember the content. This participatory learning model also helped the teacher deliver lessons more efficiently since students were more attentive and actively involved in different tasks.

The teacher views the teaching method as positively influencing effective teaching, engaging lessons, and enhancing conceptual understanding. The attribute of PjBL may have motivated the teacher to apply this teaching practice. Indeed, Yang et al. (2021) and Safitri (2024) argued that hands-on approaches in PjBL, enhance the teaching and learning through motivating students to explore, experiment, and discover, fostering greater engagement. Researchers such as Karan and Brown (2022) and Ningsih et al. (2020) highlighted that PjBL fosters deeper understanding by allowing students to apply classroom knowledge in authentic contexts. In addition, Studies by Haatainen and Aksela (2021) argued that PjBL promotes active learning by turning abstract concepts into tangible experiences.

5 Conclusion and the mode of use

The study was conducted following the gap found in the lack of tools appropriate to assess the PjBL-led instructions. The findings from this study suggest that the LOTPBL is a valid and reliable tool for assessing project-based learning within the Rwandan competence-based curriculum. The tool has a strong reliability

(Kappa = 0.8) demonstrating its effectiveness in capturing the implementation of PjBL showing a promise for generalizability. However, its application to other educational systems and cultural contexts would require careful adaptation in terms of curriculum frameworks, pedagogical norms, and teacher training approaches. Therefore, LOTPBL may need contextual adjustments and re-validation to ensure cultural relevance and effectiveness in diverse settings. Nonetheless, the tool holds significant potential for supporting the global shift toward competency-based and active learning methodologies.

The study has limitations such as employing one participant teacher, the observer's bias, and a short period of training. While the tool is described as adaptable to other contexts, its effectiveness and relevance in different cultural, curricular, or instructional settings were not empirically tested. These limitations leave questions about its applicability beyond the original study environment. Further research such as examining long-term changes in student outcomes due to the use of LOTPBL and exploring how the tool can be adapted for different educational systems globally should be conducted. Further improvements or revisions of the tool are anticipated based on users or researchers' observations.

The LOTPBL can be used in the following modes:

(a) The tool is used after 2 h of training. During the training, users may calculate inter-rater reliability. The inter-rater reliability (Cohen Kappa Coefficient) should be strong, indicating a deep understanding of the tool.
(b) The LOTPBL may be used by teachers for self-evaluation during professional development or by education evaluators to evaluate the implementation of a competence-based curriculum.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by UR-CE Research Screening and Ethics Clearance Committee (RSEC-C) through the Research and Innovation Unit with reference number Ref: DRI-CE/031(a)/EN/gi/2024. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

FU: Conceptualization, Writing – original draft, Methodology. JM: Writing – review & editing, Supervision. AU: Validation, Writing – review & editing, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1623269/full#supplementary-material

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