Effectiveness of Continuous Professional Development Training on Lower Secondary School Mathematics and Science Teachers' Content Knowledge in Rwanda

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Abstract
The present research aimed to showcase the progress made by Mathematics and Science teachers at the lower secondary school level who participated in Continuous Professional Development (CPD) training sponsored by the World Bank Group through the Rwanda Quality Basic Education for Human Capital Development (RQBEHCD) project's Subcomponent 1.2. The study encompassed 652 teachers specializing in mathematics, physics, chemistry, and biology. Pre- and post-tests were given to teachers before and after the CPD training, using a quasi-experimental research methodology. The data were analyzed using Microsoft Excel 2016 and SPSS v.25. Results demonstrate a considerable improvement in teachers' understanding of the subject, as well as significant learning gains in their teaching careers. Significant gains were found in female chemistry teachers performing better than male chemistry teachers. It is recommended that further CPD trainings are required to further improve teachers' subject knowledge.

Keywords: Assessment; CPD Training; Conceptual understanding; Content knowledge; Performance; Teachers

Introduction

The study on the effectiveness of Continuous Professional Development Training on Lower Secondary School Mathematics and Science Teachers' Content Knowledge in Rwanda is set in a multidimensional setting that represents the country's evolving educational landscape. The implementation of the competence-based curriculum in 2015 emphasizes the importance of continual teacher development to conform to shifting educational paradigms. Furthermore, the dedication to gender inclusion is reflected in the Education for All Goal, which emphasizes the significance of addressing the special needs of female teachers. The incorporation of ICT educational programs emphasizes the importance of technology in modern education even more (Nsabayezu, Iyamuremye, Mbonyiryivuze, et al., 2023 a; Nsabayezu, , et al., 2023b) Furthermore, the broader goal of contributing to economic progress through education is highlighted, with a focus on empowering both male and female Science and Mathematics educators. Thus, the study functions within a broad framework, demonstrating the interconnection of curriculum modification, gender inclusion, technological integration, and socioeconomic growth in the context of Rwanda's education system (MINECOFIN), 2013).

Research conducted by Mohd et al. (2015) indicates a correlation between students' subpar academic performance and deficiencies in teachers' content knowledge, pedagogy, and skills. Consequently, there is a recognized necessity for ongoing professional development to enhance the expertise of science teachers. The World

Bank is actively contributing to the enhancement of science and math education in Sub-Saharan African (SSA) nations (Blom et al., 2016), indicated that for SSA nations to participate fully on the global economy, they must improve their performance in Science, Technology, Engineering, and Mathematics (STEM) courses. The genesis of the issue can be traced back to the observation of subpar performance across diverse academic disciplines. The ensuing concern revolves around the notion that substandard educational quality might be a contributing factor to the sluggish pace of economic advancement in Sub-Saharan African (SSA) nations. This logical sequence underscores the critical link between academic achievement and economic progress, signalling the imperative for addressing educational shortcomings to catalyze sustainable economic development in the region (Ejiwale, 2016). In Rwanda, a noticeable decline in performance in Science and Mathematics, as highlighted in a study by Nsengimana et al. (2017), prompted a response in the context of the country's broader educational goals. With a focus on rebuilding the nation, Rwanda is committed to implementing a robust educational policy aimed at eradicating illiteracy through national capacity building grounded in science and technology. As articulated by the Rwanda Education Board (REB) in 2015, the initiative to strengthen Science and Mathematics Teaching is a pivotal aspect of this strategy. The Rwandan government, in collaboration with the World Bank, is driving the "Rwanda Quality Basic Education for Human Capital Development" (QBEHCD) initiative. This comprehensive program seeks to enhance the professional development of Mathematics and Science teachers with a specific aim of elevating teaching quality and student learning outcomes. Key priorities within this initiative encompass improving teacher content understanding, enhancing teaching practices, ensuring access to instructional resources and technology, and providing continuous support. The primary beneficiaries of these efforts are lower-secondary pupils and teachers. Recognizing the need for targeted improvement in Chemistry teaching, the University of Rwanda College of Education (URCE) and the Rwanda Basic Education Board (REB) collaboratively designed the Continuous Professional Development Certificate in Innovative Teaching Mathematics and Science (CPD ITMS), reflecting a strategic commitment to enhancing teacher competence in the specified domain.

Aims of study

The current study sought to investigate the effectiveness of Continuous Professional Development Training on Lower Secondary School Mathematics and Science Teachers' Content Knowledge in Rwanda.

Research hypotheses

Null hypothesis (Ho_1): There is no statistically significant difference in lower secondary school Mathematics and science teachers' content knowledge before and after training.

Literature Review

Continuing Professional Development (CPD) is essential for mathematics and science teachers to keep up with changing educational standards and techniques (Nkundabakura et al., 2023). This literature review explores the usefulness of CPD programs in improving pedagogical abilities, topic understanding, and student learning outcomes.

This review seeks to identify successful CPD practices and areas for development in mathematics and science teaching by evaluating a wide range of scholarly articles and research papers. The findings will help educators, policymakers, and institutions optimize CPD activities and assure continuing growth and achievement in these essential subjects. According to Bunane & Karegeya (2022), Professional development programs significantly influence chemistry teachers by augmenting their pedagogical skills and subject knowledge. Educators specializing in biology, chemistry, physics, and mathematics in Rwanda express a need for enhancing their content knowledge, improving ICT proficiency, and mastering the utilization of pedagogical kits. They emphasize the importance of regular training sessions and workshops to enhance their teaching abilities (Mugiraneza, 2021).

Supovitz and Turner (2000) identified a noteworthy association between teachers' engagement in professional development and the incorporation of inquiry-based teaching practices, along with fostering an investigative classroom culture. They underscored that the level of individual teacher content preparation plays a crucial role in shaping both teaching practices and the overall classroom culture. In a separate study, Ndayambaje and Ngendahayo (2014) reported positive outcomes from teacher training in ICT integration for education, highlighting its favorable impact on the teaching process. Consequently, as part of continuous professional development (CPD), teachers have the opportunity to improve their technological and pedagogical expertise, facilitating the seamless integration of ICT into the teaching and learning processes. Rwanda reported lower results in Sciences and Mathematics (Nsengimana *et al*., 2017). The poor achievements in Rwanda's mathematics and science classes led to the implementation of CPD training to increase the subject matter and methodological literacy of the country's secondary school Mathematics and science teachers. In their study, Nkundabakura, et al. (2023) recommend that mathematics and science teachers need more CPD training to increase the content knowledge and pedagogical knowledge (Nkundabakura et al.,2023). Nunguye et al. (2023) reported that there should consequently be more chances for teachers training to enhance their professional development. CPD programs will have a larger impact on the professional development of biology educators and will raise the standard of biology instruction by removing obstacles to participation and offering financial support. The uniqueness of this study comes from the fact that it is the first of its kind to be conducted in Rwanda and that no other comparable studies have been finished there. This study presents the results of a training program on Rwanda Quality Basic Education for Human Capital Development (RQBEHCD) on the methodology and content knowledge of mathematics and science teachers.

Methodology

Research design

This study used Milun et al. (2005)'s quasi-experimental one-group pre-posttest design. The choice is most likely influenced by practical and ethical restrictions, as random group assignment may not be viable. The methodology, which is based on a prior study, stresses a naturalistic context, allowing researchers to monitor and analyze changes caused by an intervention within a single participant group. By choosing this design, the researchers strike a balance

between methodological simplicity and the need for real-world relevance. The study targeted a population of 1100 Rwandan teachers from eight districts in the 2021 cohort. From this larger population, a specific sample of 652 mathematics and science teachers who underwent both pre- and post-tests was included in the study. Participants were not randomly assigned to groups in this design; instead, a single group received both pre-and post-tests. The study took a quantitative approach to data gathering, including pre- and post-tests to assess Chemistry teachers' performance and conceptual knowledge. The pre-test served as a baseline measure, recording beginning levels prior to the intervention, while the post-test measured changes after the intervention. The study used this methodological technique to systematically measure the impact of a specific intervention, providing a quantitative assessment of the effectiveness of the training program on desired objectives in the field of Chemistry education.

Sample size and sampling techniques

The study goes into the 2021 cohort of 1100 Rwandan lower-secondary Math and Science teachers, concentrating primarily on eight of the 16 districts participating in the program. The other districts are excluded because they work with the Flemish Association for Development Cooperation and Technical Assistance (VVOB), which provides similar training. School selection criteria included things like electricity availability, public status, and secondary school accommodation at the ordinary level (O-Level). Headteachers nominated four math and science teachers for mentorship, and the study randomly selected participants from each institution, resulting in 652 instructors who took pre-and post-tests, assuring a diverse and representative sample for analysis.

Data collection

The study obtained data by administering an achievement exam to chemistry teachers both before and after the intervention. A rigorous validation process was carried out to assure the reliability and validity of the evaluation tool. The Cronbach-α coefficient was used to measure reliability and found to be 0.84 which proves the consistency and stability of results from the instrument. This included a review by research professionals, including professors and senior lecturers from the University of Rwanda. The study used a rigorous validation strategy to see whether the test was effective in accurately assessing the targeted outcomes. This strategy was critical in ensuring the overall strength of the study's data collection methodology. The emphasis on validation implies that the researchers took extensive steps to guarantee that the test employed in the study was reliable and valid for assessing the targeted parameters. This enhances the credibility and reliability of the study's conclusions, strengthening faith in the accuracy of the data acquired during the test.

Data analysis techniques

Data from Kobo Toolbox was exported to MS Excel 2016 for analysis, with responses for each question recorded. MS Excel was used for basic data analysis, and SPSS v.25 was used for inferential statistics. Five graphs were created: one exhibiting performance by topic area in both pre-and post-tests, another displaying performance by

gender, one illustrating properly and wrongly answered questions, an individual performance graph, and a graph comparing male and female performance. The following assumptions for parametric tests were validated: continuous data, sample size, normal distribution, and equality of means. Repeated measures ANOVA was employed, and the findings were graphically presented and evaluated using Wilks Lambda because no assumptions were violated.

Results

Introductory results of learning gains

To evaluate the learning gains, the Hake (1998) formula was used to determine the learning gain <g> = AvPre - AvPost)/ (100 – AvPre). The learning gains (<g>) for chemistry subject.

Learning Gains

Teachers address a few problems on physics and math tests. Teachers answered more questions than normal during chemistry and biology exams. We use the Hake (1998) formula: AvPre - AvPost)/(100 - AvPre) to calculate the overall learning gains (<g>). The maximum score is 100, and the letters "AvPost" and "AvPre" represent the average post-test and pre-test scores. It's worth noting that calculating the learning gain ratio yields the normalized learning gain. Table 2 shows teachers learning gain.

Table 2

Teachers' Learning Gains per Subject

Level	Subject	AvPre [Overall]	AvPre [Males]	AvPre [Females]	AvPost [Overall]	AvPost [Males]	AvPost [Females]	<g> Overal l	<g> Males	<g> Fema les
Secondary (S1-S3)	Maths	58.45	57.88	58.67	62.46	63.18	60.65	0.09	0.12	0.04
	Physics	43.09	43.93	40.18	49.29	49.19	46.78	0.10	0.10	0.11
	Biology	73.87	73.09	75.28	78.03	78.00	78.08	0.15	0.18	0.11
	Chemistry	59.23	58.99	59.70	66.19	65.27	68.03	0.17	0.15	0.20

The findings for each subject are summarized below. The results per question items (The number of teachers who correctly answered a specific question on a test for both the pre-and post-test).

Mathematics

According to the study, the average pre-test performance was 58%, while the average post-test performance was 62%. There was a highly significant improvement in teacher performance favoring the post-test ($F=12.840$, $p < .001$). Gender had no effect on performance ($F =.741$, $p >.390$). The first null hypothesis was rejected because there is a statistically significant difference in lower secondary school Mathematics and science teachers' content knowledge before and after training. Male and female teachers both increased their performance, with post-test scores of 60.65% for men and 63.18% for females, compared to pre-test scores of 58.67% for males and 57.88% for females.

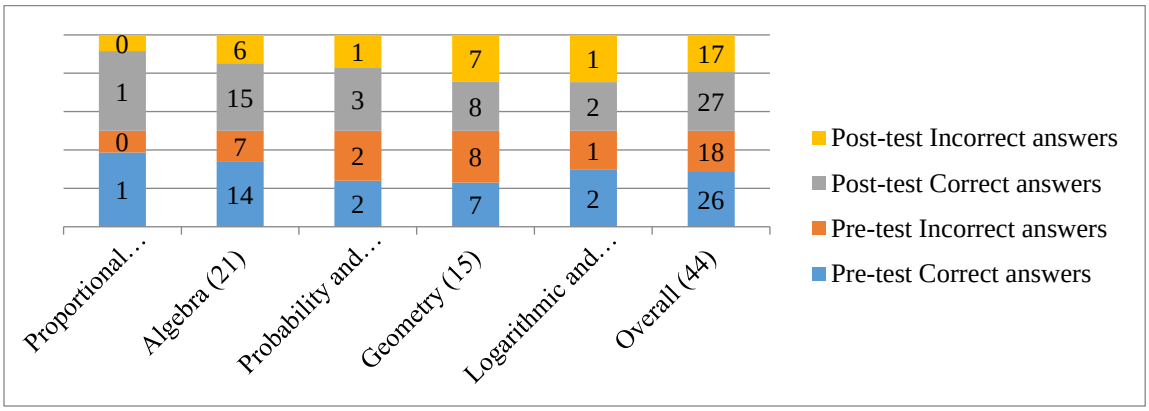
Ratios of Questions Answered Correctly by Teachers in Mathematics Topics

In Algebra, 14 and 15 out of 21 questions were answered correctly in pre-and post-tests (66.6% and 71.4%, respectively). For Statistics and Probability, two and three out of four questions (50% and 75%, respectively) were

correct. In Geometry, seven and eight out of fifteen questions were answered correctly in pre-and post-tests (46.6% and 53.3%, respectively). Two questions from logarithmic and exponential equations had the same correct solutions in both examinations. Overall, 26 of 44 questions had correct responses, with pre- and post-tests revealing answers for 27 of 44 questions (59% and 61%, respectively).

Figure 1:

Correctly and incorrectly answered questions in Mathematics topic areas for both pre-and post-test [N=44]

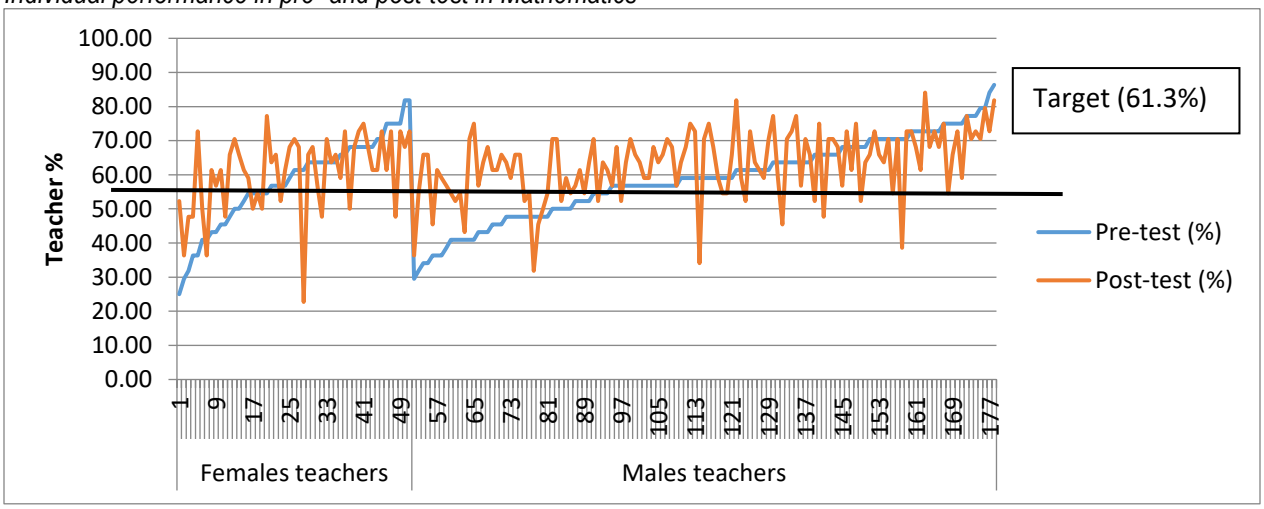


Individual Performance in Pre- and Post-Test in Mathematics

Individual pre- and post-test findings are divided into two groups in Figure 2: females (1-51) and male teachers (25-127). Some questions saw swings in performance when pre-test scores were arranged by gender. Most male teachers improved in the post-test, but not T78, T133, or T157. Females T1, T5, T9, T14, and T21 performed well in the post-test, but T27 and 48 struggled. Overall, 62.7% of girls and 63.7% of males reached or exceeded the target, indicating that both genders are improving their performance.

Figure 2:

Individual performance in pre- and post-test in Mathematics



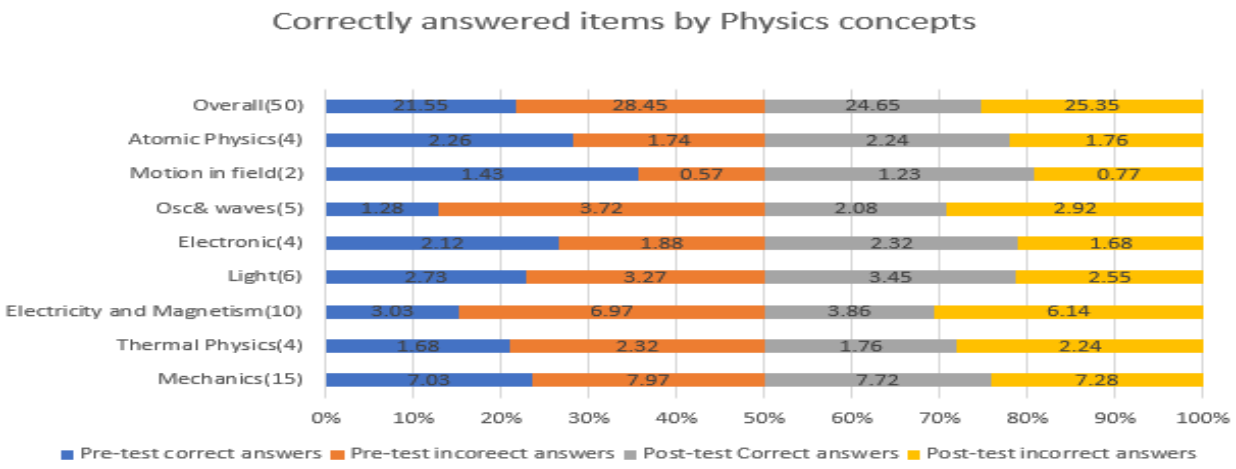
Physics

The pre-test mean increased from 43.09% to 49.29% in the post-test, a significant difference (Mean (x) for pre-test: $\bar{x}$ = 43.09, x for post-test: $\bar{x}$ = 49.29, df = 1, p < .001). Female teachers improved from 41.15% pre-training to 46.78% post-training, while male teachers improved from 43.54% to 50.01%. However, there was no statistically significant difference between male and female teachers. This rejects the first null hypothesis for conceptual understanding but supports the second null hypothesis for gender differences.

Ratios of Questions Answered Correctly in Physics Topics

The study employed 50 questions to evaluate a physics teacher's performance across eight lower secondary school areas. 49% of post-test questions and 43% of pre-test questions had accurate responses, suggesting a 6% improvement. Figure 4 depicts the success percentages for both pre-test and post-test physics questions.

Figure 3:
Correctly and incorrectly answered questions in subject topic areas for both pre-and post-test [N =50]



In Mechanics, 46.86% were correct in the pre-test, whereas 53.13% were correct in the post-test. In Thermal Physics, 41.75% of the pre-test questions were correct, while 44% of the post-test questions were correct. 30.3% pre-test and 38.6% post-test for electricity and magnetism. Light scored 45.5% in the pre-test and 57.5% in the post-test. Electronics, 53% pre-test and 58% post-test. Oscillation and waves: 25.6% pre-test, 41.6% post-test. Motion in Field: 71.5% pre-test, 61.5% post-test. Atomic Physics: 56.5% pre-test, 56% post-test. Some topics improved, although Motion in Field and Atomic Physics fell by about 5% and 0.5%, respectively, in the post-test, potentially due to a variety of variables.

Individual teacher performance

Figure 4 depicts the rise or decrease for individual teachers from pre- to post-test following training. The study included 148 teachers (33 females and 115 males). Female teachers are numbered from 1 to 33 on the horizontal axis, whereas male teachers are numbered from 1 to 115. Each teacher's pre-test and post-test scores are superimposed on different lines. For example, female teacher-1 and male teacher-1 both scored 24% on the pre-test and 60% on the post-test. Overall, 17 (52%) of female teachers outperformed the objective (47.67%), whereas 68 (59%) outperformed the target.

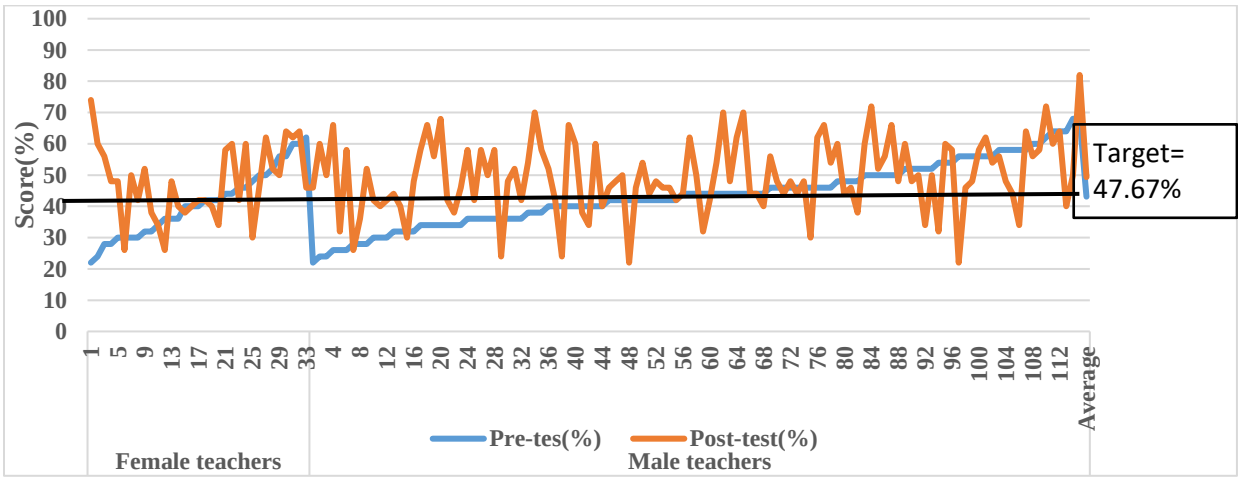


Figure 4 Individual teacher performance from pre-to post-test in Physics

Chemistry

The results demonstrated a statistically significant difference between the pre-test and post-test (Mean in Pre-Test $\bar{x}$ = 59.22, Mean in Post-Test $\bar{x}$ = 66.18, df = 1, p <.001). Furthermore, a significant difference favouring female professors over men was detected in both the pre-test and post-test (Mean of females = 68.0373, Mean of males $\bar{x}$ = 66.18, d.f = 1, p < .01). The intervention had a significant influence on teachers' grasp of chemical issues, with a minor effect on gender disparities. The first null hypothesis was rejected due to a substantial difference in comprehension between pre-and post-training. The second null hypothesis was accepted, revealing gender inequalities in mathematics and science teachers. Female teachers routinely outperformed male teachers in both pre-and post-testing.

Correctly Answered Questions in Chemistry Topic Area for both Pre-and Post-Test

Figure 6 shows the pre-and post-test results for chemical questions. These questions covered 2 organic chemistry, 25 organic chemistry, 10 atomic structure and periodic table questions, and 1 Particulate Nature of Matter question. The pre-test had 26.13% accurate answers (68.76% incorrect), whereas the post-test had 32.27% correct answers (84.92% incorrect). This signifies improved performance in the post-test. Organic chemistry had 77.5% correct on the pre-test and 84.5% correct on the post-test, scope chemistry and particle nature of matter had 76% correct on the

pre-test and 78% correct on the post-test, and atomic structure and the periodic table had 67.4% and 78% correct, respectively.

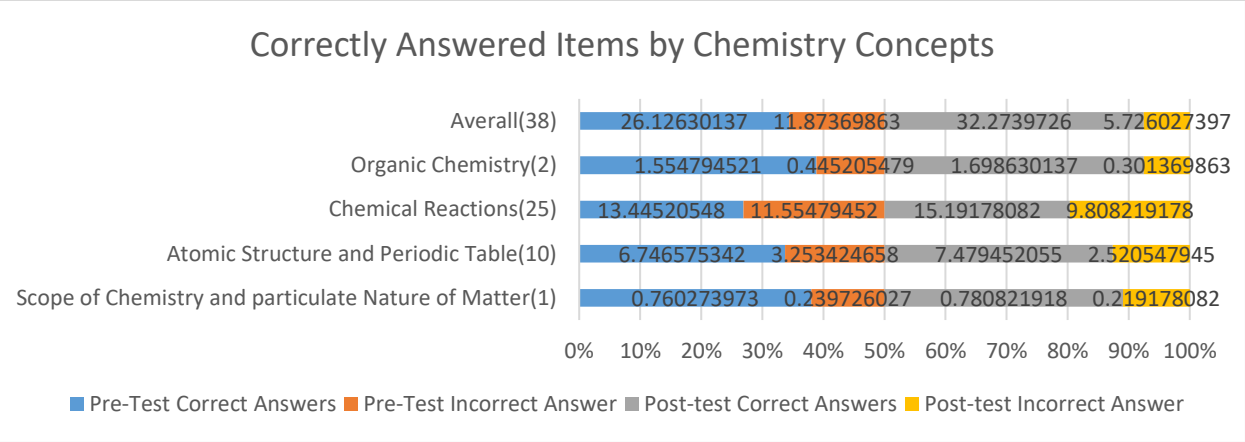


Figure 6: Correctly and incorrectly answered questions in chemistry topic areas for both pre-and post-test [38]

Individual Teacher's Performance in Chemistry

Figure 7 displays chemistry teacher pre- and post-test performance, combining findings by gender. Female teachers in positions 1-4 scored 35-45% on the pre-test and 58-86% on the post-test. Male teachers in slots 1-4 scored 46-48% pre-test scores and 74-86% post-test scores. Overall, 86 male teachers outperformed the target, whereas 41 out of 48 female teachers outperformed (62.49%).

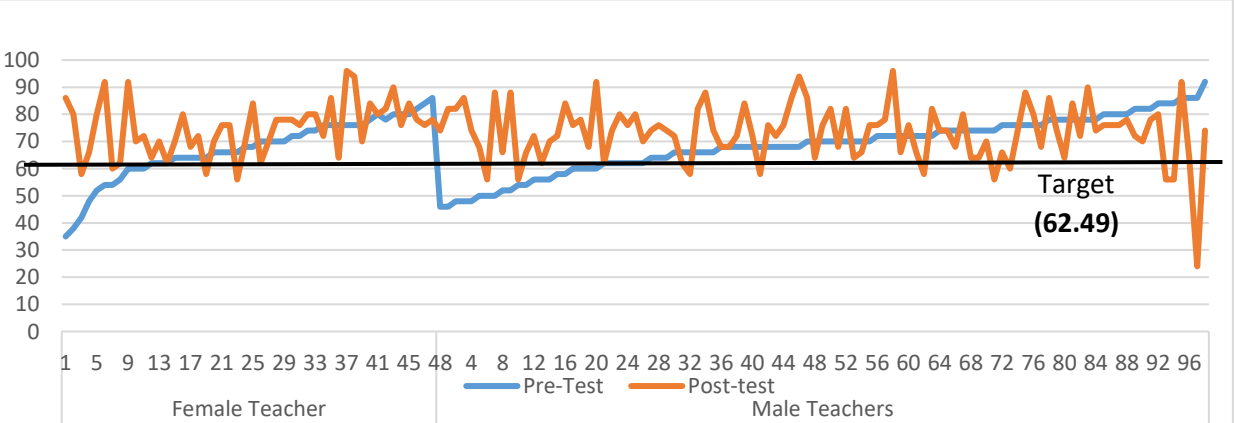


Figure 7: Individual Teacher's performance in pre-and post-test in chemistry [N=146]

Biology

The improvement was remarkable, with a $p < .0001.$, df=1, N=116. The training consequently has a favorable effect on teachers' performance. Tecahers' performance increased from a pre-test score of 73.8% to a post-test score of 78.0%. However, there is no statistically significant difference between male and female teachers. Since there is a

statistically significant difference in the conceptual comprehension of mathematics and science teachers before and after training, the first null hypothesis is disproved. Because no statistically significant difference exists between male and female mathematics and science teachers' conceptual comprehension, the second null hypothesis is also rejected.

Correctly Answered Questions in Biology Topic Areas for both Pre and Post- Test

The percentages in the topic areas show how many of the desired things have been fulfilled in that specific area. In the domain of genetics and its applications, for instance, six questions were given, with 3.83 correctly answered in the pre-test and 4.18 correctly answered in the post-test. In general, each topic area has had more correctly answered questions on the post-test than on the pre-test. These results lead us to believe that the trainings have a positive effect on teachers' conceptual knowledge.

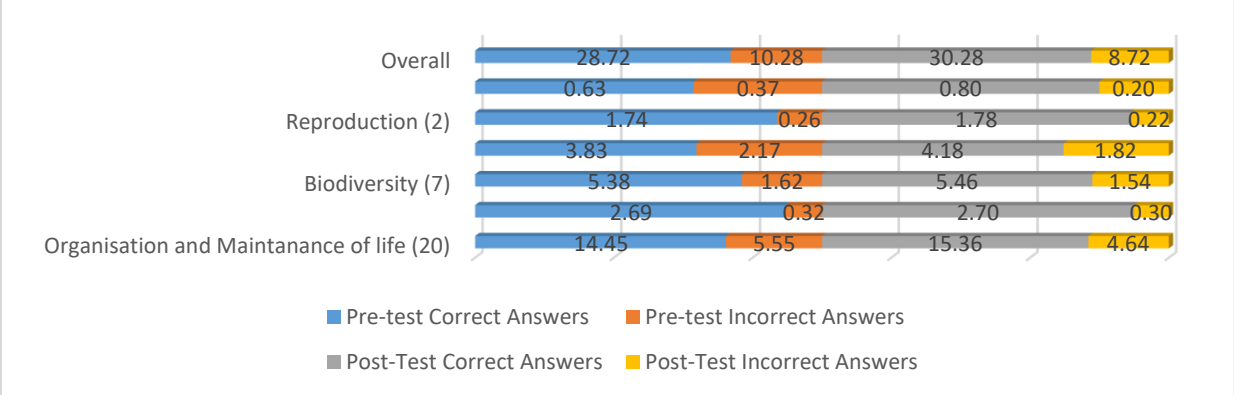


Figure 9: Correctly and incorrectly answered questions in Biology topic areas for both pre-and post-test (N= 39)

Biology test results for each teacher, broken down by gender. Figure 11 below demonstrates that while most teachers, both male and female, scored more than 50% on the pre-test and that a sizable fraction of teachers even exceeded the target score of 75.93% for the trainings. The post-test results for certain male and female teachers showed remarkable improvement; for instance, teacher number one's post-test score of 76.52% compared to her pre-test score of 38.98%. This suggests that the trainings had a positive effect on the biology teaching performance of the teachers, and as can be seen in the graph below, teachers with pre-test scores below 50% did well on the post-test. However, some teachers' performance decreased, as shown in Figure 11 below, which implies that their post-test scores dropped below their pre-test scores.

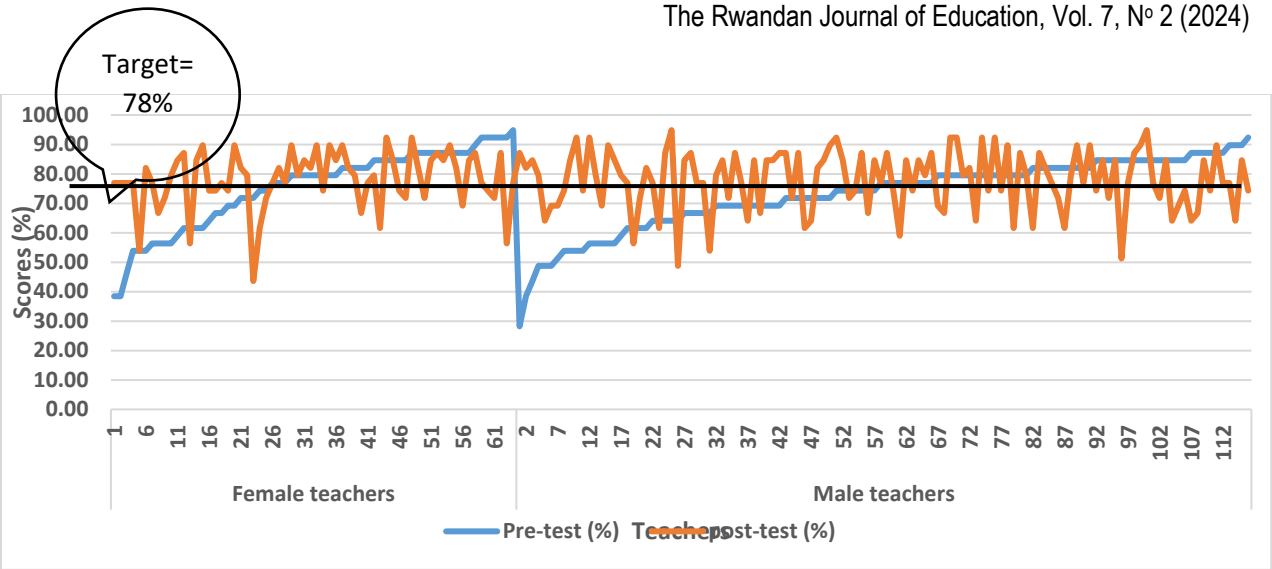


Figure 11: Individual teachers' performance in pre and post-test in biology. [All (N= 180); Female (N= 64); Male (N=116)]

Discussion

In Mathematics Subject

Despite demonstrating proficiency in both pre-and post-tests, persistent challenges surfaced in specific questions during both assessments. Notably, in question Q14, teachers struggled to determine the equation of a line given a point (-3, 2) and a slope of 5, revealing a deficiency in fundamental concepts such as slope, y-intercepts, and x-intercepts. This reflects a broader issue with the abstract nature of algebra, acknowledged as a consistent challenge for both teachers and students (Mukuka et al., 2019). Further analysis exposed weaknesses in teachers' perspectives on function concepts, leading to errors in solving equations and manipulating algebraic functions. Additionally, difficulties were observed in comprehending various classes of angles. Sunzuma and Maharaj (2019) underscored that 40% of trained teachers-maintained misconceptions about Geometry even after training, highlighting the struggle faced by educators without sufficient support in mastering Geometry topics. Surprisingly, our data showed no gender disparities in performance, indicating that ongoing support can enhance teachers' effectiveness. To foster competent in-service teachers capable of seamlessly integrating mathematical concepts with real-world applications, there is a pressing need for improved content and pedagogical skills. This emphasis on professional development aligns with the goal of boosting O' Level students' mathematical performance and interest (Habiyaremye, 2016; Ukobizaba et al., 2019).

In Physics Subject

Significant statistical differences ($p < .001$) emerged between the pre-test and post-test phases, although the effect size was modest ($\eta 2 = .111$). This aligns with Ndihokubwayo et al.'s (2022) findings, revealing a deficiency in students' understanding of science and physics concepts, emphasizing the critical need for effective training of physics teachers. Interestingly, no statistical difference was observed between male and female teachers ($p > .05$),

echoing Lorenzo et al.'s (2006) assertion that gender gaps diminish with teaching approaches involving interactivity, collaboration, and competition. The third finding highlighted challenges in specific physics questions and misconceptions among lower secondary teachers, unexpectedly paralleling the content in the Rwandan competence curriculum (REB, 2015). The training manual, encompassing eight units, demonstrated an overall improvement of 24.65 or 49.3% post-training. However, lingering misconceptions and challenges were noted in specific topics, as exemplified by the Electricity and Magnetism question (Q24, image A), emphasizing nuanced hurdles that persist despite the achieved overall progress.

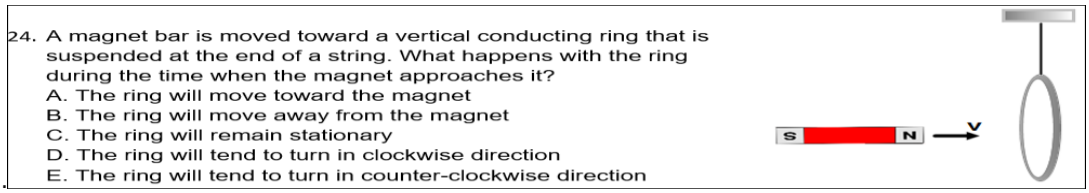


Figure A Sample question related to magnetism

Instead of predicting that "the ring will move away from the magnet (B)," a significant number of teachers instead asserted that "the ring will remain stationary." These findings align with the results of a study by Uwizeyimana et al. (2018), which highlighted that inadequate teaching approaches, including Continuous Professional Development (CPD), failed to address misconceptions and professionalize teachers effectively. Notably, misconceptions in electricity and magnetism were specifically observed among physics teachers, paralleling the misunderstanding experienced by senior two students who erroneously believed that a battery served as a continuous current source, as noted by Mbonyiryivuze et al. (2019). This misconception among teachers appears to be directly proportional to their own misunderstandings and a lack of robust physics content knowledge.

In Chemistry subject

A trained chemistry teacher's performance improved dramatically, with pre-test to post-test mean score gains of 59.23% and 66.19%, respectively, correlating with Pilo *et al.* 's (2012) findings underlining the relevance of teacher training in boosting educational output. This strategy has a positive impact on student performance, classroom organization, and scientific topic mastery, needing additional teacher training and professional development. The observed dominance of female instructors over their male colleagues in assessments is consistent with current literature arguing for continuing, tailored professional development as a catalyst for improving teaching and learning outcomes. As Assadi et al. (2019) point out, this trend highlights the significance of personalized initiatives for teachers. The findings underscore a vital requirement for teachers to actively participate in such development programs, noting the possibility of gender-specific variances in performance and emphasizing the larger significance of continual professional growth for educators. Islahi and Nasreen (2013) discovered that both male and female teachers' performance was enhanced. Frequent CPD training sessions play a crucial role in enhancing the capabilities of both male and female teachers in effectively teaching chemical principles. Notably, the identification of

challenging questions in the realm of chemical reactions, where many teachers struggled, underscores the importance of continuous monitoring during training, as suggested by Cossa and Uamusse (2015). Recognizing the broad scope of chemistry curricula, they caution that a lack of sustained attention during training can adversely affect teachers' classroom performance. Hence, there is a compelling need for ongoing education to address the evolving demands of teachers' professional journeys. The implementation of Continuous Professional Development (CPD) emerges as pivotal, influencing both professional and personal growth. The impacts of CPD initiatives, including skill enhancement, incorporation of innovative teaching methods, retention of acquired knowledge, and the promotion of creativity, as emphasized by Ukachi and Onuoha (2014), underscore its comprehensive influence, affirming its role in fostering continual growth and adaptability for educators throughout their careers.

In Biology Subject

In the realm of biology, the p-value analysis indicates an absence of correlation between gender and teacher performance, surpassing the 0.05 threshold. This finding is consistent with Mukagihana et al.'s (2021) discovery of no statistically significant gender-based differences among pre-service biology teachers after three interventions. While our study shows encouraging outcomes regarding overall biology teacher performance, a notable portion fell short of the target. Furthermore, some educators still grapple with misconceptions and encounter challenges with specific concepts in the subject, highlighting the intricacies of addressing biology education challenges despite favorable trends. Notably, Question 19, pertaining to gene technology, emerged as particularly challenging, with correct responses remaining at 13% in both pre-test and post-test phases. Similarly, Oztas and Oztas (2016) affirmed the inherent difficulty for teachers in explaining genetic engineering mechanisms without specialized instruments.

Consequently, there is a pressing need for continuous professional support to help teachers overcome preconceived notions. Questions 23 and 13 also posed challenges, aligning with the senior three Rwandan curriculum in distinct units. The difficulty observed in Question 23 could be linked to teacher misinterpretation, as noted in a previous study by Abe and Owoeye (2012). Recognizing teachers' pivotal role, as emphasized by Ongowo (2013), our stance is that no teacher should be overlooked in rectifying biological misconceptions. The study underscores the importance of providing targeted assistance to enhance both specific misconceptions and overall teacher performance and confidence in the teaching profession. In essence, a comprehensive approach to addressing individual teacher needs in comprehending and conveying biological topics can significantly contribute to an enhanced educational environment.

Conclusion

This study investigated how continuous professional development, or CPD, training affected the proficiency and performance of Rwandan lower secondary school mathematics and science teachers. The overall improvement in teacher performance, as seen by better conceptual understanding and classroom practices from pre-test to post-test, is remarkable. However, the found gender-based differences in subject performance highlight the need for focused

interventions such as tailored mentoring programs, specialized seminars, or gender-sensitive teaching styles to address and mitigate the revealed discrepancies. Despite the overall progress made, persisting issues across subjects underscore the importance of correcting specific misconceptions in future training sessions. To address these challenges and improve topic understanding, teachers should participate in additional continuing professional development (CPD) training, with a focus on algebra in mathematics, chemical reactions and organic chemistry in chemistry, oscillations and waves in physics, and genetics in biology. This ongoing commitment to professional development aims to continually elevate teacher competence, correct misconceptions, and contribute to the continuous improvement of mathematics and science education in lower secondary schools in Rwanda.

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