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Enhancing physical sciences performance through formative assessment strategies

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Abstract

This study explored the impact of integrating formative assessment practices on improving academic performance among learners in Physical Sciences classrooms. Simple random sampling was utilised in the UMkhanyakude District of KwaZulu-Natal Province, South Africa, to select participants. A quasi-experimental design employing pretest and post-test comparisons was employed, with five secondary schools involved, three comprising an experimental group and two forming a control group. A total of 175 Grade 10 Physical Sciences learners from the selected schools participated in the study. Three teachers from experimental schools underwent training in utilising formative assessment practices, while two teachers from the control group continued with their regular instructional methods without exposure to formative assessment practices. The study was guided by the Assessment for Formative Purpose Cycle as a conceptual framework to explore how formative assessment practices could enhance academic achievement. Data analysis was conducted using SPSS Version 26, employing a 2-way ANOVA statistical technique. Results indicated that students from experimental schools, where the intervention was implemented, demonstrated significantly higher performance compared to those from control schools following standard classroom instruction. The findings suggest the importance of integrating formative assessment practices into the teaching of Physical Sciences within the South African education system to improve learners' conceptual understanding and foster independent learning in the subject.

Keywords: Academic Performance, Physical Sciences, Formative Assessment, Teaching Strategies, Learning Approaches

Introduction

The primary objective of learning activities is to enhance the academic achievement of students in Physical Sciences. According to Linn, Tashiro, Morio, and Hori (2022), academic achievement refers to the learning outcomes achieved by students following a set of learning activities. To optimise the academic success of Physical Sciences learners, formative feedback they receive during science activities must motivate them to recognise and address any existing gaps in their understanding (Selvaraj & Azman, 2020). Conversely, the absence of detailed feedback from formative assessment activities can lead to difficulties in grasping scientific concepts, thereby increasing stress levels among students (Pascoe, Hetrick & Parker, 2020). Formative assessment is employed in science classrooms to ensure the effectiveness and quality of the learning process, ultimately facilitating the attainment of learning objectives. Physical Sciences educators utilise various formative assessment methods such as tests, self-assessments, peer assessments, questioning, and group discussions. However, for teachers to successfully integrate formative assessment into teaching and learning, they must perceive assessment as an integral part of the learning process rather than merely an evaluation tool (Jean de Dieu & Zhou, 2021). Assessment practices in classrooms have evolved from being solely focused on evaluating learning to actively contributing to the learning process itself (Hotaman, 2020). Incorporating assessment as a learning tool fosters metacognition and increases student engagement, consequently improving academic achievement.

Traditionally, summative assessment tends to dominate the teaching and learning process, often overshadowing formative assessment (Ganajova et al., 2021). Unlike formative assessment, which provides ongoing feedback to support learning, summative assessment primarily serves to assign grades after a unit, term, or syllabus. However, research suggests that summative assessment feedback may not effectively support learners in achieving learning objectives as it tends to focus solely on outcomes rather than the learning process itself (Al Tayib Umar & Ameen, 2021). Scholars advocate for a shift towards emphasising formative assessment activities that facilitate ongoing learning and progress evaluation (Braund & DeLuca, 2018).

Formative feedback emerges as a promising solution to address this issue, as it enables students to identify strengths and weaknesses early in the learning process (Pentra et al., 2022). Timely and accurate formative feedback plays a crucial role in enhancing students' scientific understanding and academic achievement, despite potential challenges in implementation, particularly in rural schools (Malone, 2022). Additionally, formative assessment serves as an effective instructional strategy to promote students' self-regulation skills and attitudes towards learning, thereby preparing them for real-world challenges beyond schooling. While numerous studies demonstrate the positive impact of formative assessment feedback on academic achievement, there remains a gap in understanding which instructional strategies can comprehensively enhance formative assessment practices, including informal tests, peer assessment, self-assessment, group discussion, concept cartoons, and concept maps (Mngomezulu, et al., 2024).

Incorporating formative assessment strategies into teaching and learning in Physical Sciences has been shown to significantly enhance academic performance by actively engaging students in the learning process. These strategies, such as regular quizzes, peer assessments, think-pair-share activities, and self-assessments, allow teachers to monitor students' understanding and provide timely feedback. In Physical Science, where concepts like physics laws, chemical reactions, and mathematical modelling can be complex, formative assessments help students identify areas of difficulty and correct misconceptions early. For example, using frequent short quizzes on topics like thermodynamics or mechanics can pinpoint gaps in understanding, giving teachers the chance to adjust lesson plans and target specific problem areas. This approach fosters a deeper, more personalized learning experience for students, making abstract concepts more accessible and memorable.

This study seeks to address this gap by focusing on maximising the academic achievement of Physical Sciences learners through the integration of comprehensive formative assessment practices. The research aims to comprehensively integrate formative assessment practices into science teaching and learning and observe their effects on academic achievement. As advocated by Black and Wiliam (2018), incorporating formative assessment into classroom practices is essential for providing valuable feedback and guiding students' learning processes. By providing learners with insights into their learning deficits and weaknesses, formative assessment practices can drive follow-up activities aimed at improving learning outcomes.

Purpose of the study

The purpose of the study is to investigate the impact of integrating formative assessment strategies on academic performance in the field of Physical Sciences. The study explored how the incorporation of formative assessment practices into teaching and learning approaches can improve learners' academic achievement in Physical Sciences classrooms. By examining the effectiveness of formative assessment techniques such as tests, self-assessments, peer assessments, questioning, and group discussions, the research seeks to provide insights into how teachers can optimise the learning process and facilitate the attainment of desired learning outcomes in the realm of Physical Sciences. The empirical investigation was guided by the research question: What is the effect of formative assessment intervention practices on maximising learners' academic achievement in Physical Sciences teaching and learning?

Conceptual Framework

The Assessment for Formative Purpose Cycle (AFPC) serves as the conceptual framework underpinning this study, establishing its structural groundwork. By offering comprehensive insights, the AFPC guides the successful incorporation of formative assessment within classroom settings, thereby bolstering learners' academic accomplishments. Positioned at the core of the cycle, learners actively participate in the learning process. Figure 1 below depicts the Assessment for Formative Purpose Cycle.

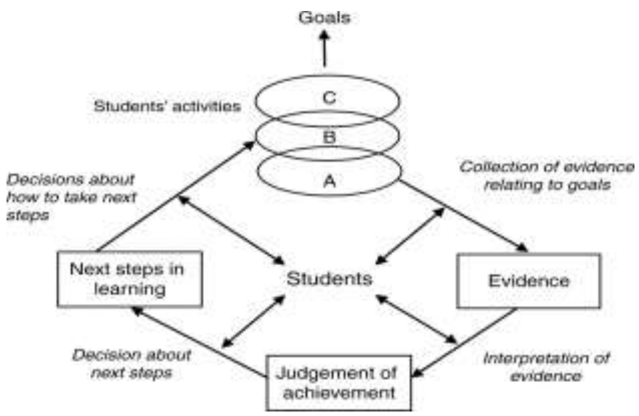

Figure 1: *Assessment for Formative Purpose Cycle (AFPC) [Adapted from Harlen (2006)]*

Formative assessment constitutes an ongoing cyclic process within classroom practice, as illustrated in Figure 1. Continuous gathering of information occurs to evaluate learners' progression towards the short-term objectives established for the lesson. This acquired information is subsequently employed to identify the appropriate next steps for learners and the necessary actions to facilitate those steps. It is essential to highlight that learners actively participate in the learning process, with a significant aspect of formative assessment lying in the feedback they receive to enhance their understanding or skills related to the specific concept presented. Concurrently, the information gathered on learners' progress serves as feedback for the teacher. This enables the teacher to adjust the pace or complexity of the teaching and learning activities or modify the teaching approach to optimise and provide ample learning opportunities. Learners also play a crucial role in decision-making regarding their own learning, directing their efforts more effectively when they grasp the purpose behind the presented activities. Essentially, it is not only about understanding what needs to be done but also comprehending the intended quality and learning goals. This framework is most suitable for this study as it is informed by key strategies of formative assessment as suggested by Ozan and Kincal (2018).

Literature review

Formative Assessment Practices

Formative assessment is aimed at fostering "assessment for or as learning," which involves various assessment activities designed to gather information about learners' progress, serving as evidence to adjust teacher-learner instructional strategies (Chen et al., 2021). Csapo and Malnar (2019) emphasise the importance of aligning formative assessment practices with learning goals and objectives, noting that this alignment can enhance learners' confidence and interest, ultimately improving performance. Hotaman (2020) further underscores how focusing on learning objectives and goals can enhance learners' engagement and interest in the subject matter, particularly in science classrooms where hands-on experiences play a crucial role in improving understanding. Dalby and Swan (2019) found that well-structured and consistent formative assessment activities can lead to improvements in learners' achievement.

The integration of formative assessment aims to support learners in developing their understanding, capabilities, and skills by refining assessment through collective feedback (Panedero et al., 2019). Dayal (2021) highlights how formative assessments serve as feedback mechanisms that guide teaching and learning processes, ultimately enhancing learning outcomes. Formative assessment strategies must be accompanied by constructive and detailed feedback to support learners' improvement and enable teachers to adjust their instructional methods to cater to diverse learners (Lipnevich & Panadero, 2021). Peer and self-assessment have been identified as effective formative assessment strategies that positively influence learners' academic achievement and support inquiry-based science learning (Yan & Brown, 2017; Zulliger et al., 2022). However, it is essential to structure these assessments carefully to prevent biases and ensure desired outcomes (Grob et al., 2017).

The literature underscores the centrality of feedback in formative assessment strategies and its impact on learners' achievement. However, there is a gap in research regarding the comprehensive integration of formative assessment practices to maximise academic achievement in Physical Sciences teaching and learning. This study seeks to address this gap by comprehensively integrating various formative assessment strategies such as questioning, peer assessment, self-assessment, and concept maps to improve learners' academic achievement in science classrooms.

Academic Achievement

Academic achievement represents the learning outcomes attained by learners following a series of educational endeavours. Optimal academic achievement occurs when learners reach their full potential based on their learning capacities. De Agular et al. (2020) define learning capacity as the ability of individuals to comprehend, assimilate, and apply existing knowledge. Sancho-Zamora et al. (2022) express concerns that various disruptions and events during the feedback reception process may hinder the optimisation of learners' learning abilities. Therefore, Sujito et al. (2021) stress the need for innovative approaches in the learning process that offer enhanced feedback to bolster learners' academic achievements. Several studies suggest that formative assessment activities conducted during each learning session can maximise and enhance learners' academic achievements. Andrade (2019) asserts that the primary aim of formative assessment is to rectify and enhance learning outcomes. Dalby and Swan (2019) support Andrade's (2019) viewpoint, affirming that formative assessment indeed contributes to improving learners' academic performance.

Methods

Research design

This study employed a quasi-experimental design, with purposive sampling considered appropriate. Thyer (2012) highlighted that quasi-experimental research is commonly utilised to assess various aspects, such as social work programmes and existing policies. The study adopted a 2×2 factorial design, with the dependent variables being academic achievement measured through pre-test and post-test scores of the Grade 10 Physical Sciences Test on Electricity and Magnetism. The independent variable in this research is the learning process. Specifically, the learning process served as the treatment variable, with two groups established: (1) Experimental group, where the learning process integrated formative assessment intervention practices, including pre-test and post-test assessments; (2) Control group, where the learning process involved only pre-test and post-test assessments without formative assessment intervention practices. During the learning process, learners received feedback from the teacher on their performance after completing the pre-test and post-test assessments.

Participants

This study involved Grade 10 Physical Science learners selected from five secondary schools in the UMkhanyakude District. The total number of participants was 175 students, divided into two groups. The experimental group comprised 118 learners, while the control group consisted of 57 learners. Table 1 provides the breakdown of the number of learners by school and by group, illustrating the distribution of participants in the intervention and control groups across the five secondary schools involved in the study. The UMkhanyakude District has 11 circuit clusters; the sampled schools were all from one cluster. The sampled schools are characterized by poor performance in Physical Sciences. As a result, the researcher opted to do research, and the focus was on grade 10, ever since it is the entry grade to FET, and that is where teachers are expected to lay the solid. For each school, the table shows the number of learners allocated to the intervention group and the percentage this represents of the total number of participants in that group. Similarly, it displays the number of learners assigned to the control group and the corresponding percentage. For example, in School A, 26 learners, accounting for 22.0% of the total intervention group, participated in the intervention, while another 26 learners, constituting 14.9% of the total control group, were assigned to the control group. This breakdown is repeated for each school involved in the study, providing a comprehensive overview of the distribution of participants across both intervention and control groups. The totals at the bottom of the table summarise the number of learners in each group across all schools, along with the corresponding percentages.

Table 1: *Number of learners by school and by group*

	Intervention	**Intervention**	**Control**	**Control**	**Total**	**Total**
School	n	%	n	%	n	%
A	26	22.0%			26	14.9
B	40	33.9%			40	22.9
C	52	44.1%			52	29.8
D			18	31.6%	18	10.3
E			39	68.4%	39	22.9
Total	118	100.0%	57	100.0%	175	100.0

Table 2 provides details on the gender representation of the respondents, with a total sample size of 175 participants. For each gender category (male and female), the table presents the number of participants and the corresponding percentage within both the intervention and control groups. For instance, in the intervention group, there were 68 male participants, constituting 57.6% of the total intervention group, and 50 female participants, accounting for 42.4% of the total intervention group. Similarly, in the control group, there were 31 male participants (54.4% of the total control group) and 26 female participants (45.6% of the total control group). The totals at the bottom of the table summarise the number of participants in each gender category across both intervention and control groups, along with the corresponding percentages. Overall, the table provides an overview of the gender distribution among the respondents, broken down by intervention and control groups.

Table 2. *Details on gender representation of respondents (n=175)*

	Intervention	**Intervention**	**Control**	**Control**	**Total**	**Total**
Gender	n	%	n	%	n	%
Male	68	57.6	31	54.4	99	56.6%
Female	50	42.4	26	45.6	76	43.4%
Total	118	100.0	57	100.0	175	100%

Group training for intervention

Through focused professional development, the experimental group of teachers received valuable information to guarantee the effective application of formative assessment methodologies in Physical Science classes. These teachers received training on creating and successfully using formative assessments in their classes. Workshops included a range of formative assessment methods, including the use of interactive exercises, quizzes, peer evaluations, and real-time feedback. Teachers were also given resources, including templates and examples, to help them easily integrate these tactics into their lesson plans. Mentoring provided regular follow-up help, allowing teachers to talk about difficulties, exchange experiences, and improve their strategy under the direction of subject-matter specialists. Because of this continuous involvement, teachers were guaranteed to be knowledgeable about more than just formative assessments.

However, the teachers in the control group did not receive the same degree of assistance. They persisted in using their standard teaching strategies, which might have included more conventional, summative evaluation techniques like final exams and unit-ending assessments. The control group was watched and tracked in a manner akin to that of the experimental group in order to preserve consistency and evaluate the effect of the intervention. Regarding formative assessment, they received no particular instructions or extra materials. This made it possible to compare the two groups' academic performance directly because any discrepancies could be linked to the experimental group's formative evaluation techniques. Both groups were routinely evaluated for modifications in their instructional strategies and learners' results to maintain evaluation fairness.

Instrument and Data Collection

In this study, the evaluation of academic performance involved assessing learners' comprehension, particularly their ability to provide accurate responses to a set of 25 multiple-choice questions. These questions included 21 individual questions, with one question comprising five sub-questions, and were administered in both the Pre-test and Post-test sessions (Grade 10 Physical Science Test on Electricity and Magnetism). Before data collection, the research instrument (test) underwent validation and reliability testing. Subject advisors and senior Physical Sciences teachers served as moderators to ensure the standard of the test. The validation process focused on assessing the content and face validity of the test. The test's reliability, measured using Cronbach's Alpha, was determined to be 0.8, meeting the criteria for a reliable and valid test (Taherdoost, 2016). Consistently, the same test was administered to all Grade 10 Physical Sciences learners as a class test before and after the interventions involving formative assessment practices.

Data Analysis

The data was analysed using SPSS Version 26 (Statistical Package for Social Sciences), and graphs were generated using Microsoft Excel 2021. The statistical method employed was the 2-way ANOVA with repeated measures to ensure a high level of confidence in the results.

The Intervention Practices for Formative Assessment in the Classroom

As this study aims to examine the impact of exposing the experimental group to the intervention, it is crucial to provide further details on what comprises the treatment condition or formative assessment interventions to elucidate the hypothesised effects on learners' academic achievement. The formative assessment intervention practices or treatment conditions were derived from the work of Ozan and Kincal (2018) and were adapted by the authors to align with the study's context. The instructions encompassing the 'Intervention or Treatment condition' were based on the four primary strategies of formative assessment (Ozan & Kincal, 2018) outlined in Table 3.

Table 3. *The four primary approaches to formative assessment practices*

	Where the learner is going?	Where the learner is at right now?	How the learner will get there?
Teacher	1. Explaining and clarifying learning objectives and success criteria	2. Engineering effective and quality dialogue and inquiry	3. Providing feedback that moves learners forward and increases the quality of marking and record-keeping
Peer/Learner	• Learner/peer needs to understand learning objectives and success criteria	4. Using self and peer assessment (activating learners as instructional resources to one another)	

Clarifying learning objectives and success criteria understood by learners in classroom practices represents a fundamental aspect of formative assessment practices. This process involves engaging learners in the instructional process by presenting clear expectations for them to successfully achieve learning outcomes. For learners to reach these objectives, they must understand the lesson's learning targets, goals, and criteria. Consequently, lessons in experimental schools commenced with a segment where learning objectives and success criteria were explicitly stated, explained, and clarified.

Subsequently, the experimental group proceeded to delve into the core content of the Physical Sciences subject by incorporating various teaching strategies such as questioning, discussion, supervised classwork, peer assessment, feedback, and other interactive approaches, facilitating learners' engagement with the content. For instance, in School A, where 26 learners comprised the experimental group, activities were centred around the learners, with students assisting each other in understanding concepts, providing feedback on learning tasks, and taking ownership of their learning process, while the teacher served as a facilitator, employing an inquiry-based approach.

These essential strategies revolved around three primary components: (1) articulating the learning destination, (2) assessing the learner's current position, and (3) outlining the path to achieve the learning objectives. The study focused on the topic of 'electricity and magnetism' in Grade 10 and spanned three weeks, as outlined in the Annual Teaching Plan (ATP). During the first week, three one-hour lessons were conducted, followed by four one-hour lessons in the second and third weeks, totalling eleven hours dedicated to this topic. All learners studied this topic over three weeks.

In contrast, for the control group (schools D & E), teachers were instructed to teach the concept of electricity and magnetism using their typical instructional methods, such as demonstration without interactive learning. while the experimental group (Schools A, B & C) received intervention-based instruction employing the strategies outlined in Table 3.

Findings

Table 4 presents the comparison of means before the implementation of the intervention for a total sample size of 175 participants, divided into Experimental and Control groups. These findings suggest that before the implementation of the intervention, the Experimental group had significantly higher mean scores compared to the Control group. This indicates that there may have been differences in academic performance between the two groups before the intervention.

***Table 4**. Comparison of the means before the implementation of the intervention (n=175)*

Group	Mean	Range	Sd	t	P-Value
Experimental	24.6	49-4=44	7.809	7.490	P=0.000
Control	18.04	36-6=30	6.100		

It was virtually difficult to achieve the perfect balance between the control and experimental groups because the study only included five schools. It would have been challenging to match schools or choose them randomly with such a tiny sample size to guarantee equivalency between the control and experimental groups. Due to practical concerns (such as proximity to the researcher) or other limitations, schools A through C were placed in the experimental group, and schools D and E in the control group. Due to this tiny, non-randomized grouping, the schools in the experimental and control groups differed regarding resources, teacher experience, or learners' demographics.

Test of initial equivalence

Since the study took place in classroom environments, rather than randomly assigning participants to experimental and control groups, researchers opted to verify the comparability of both groups before implementing the respective formative assessment practices as an intervention. This step aimed to lay a robust groundwork for subsequent analyses and interpretations, thereby safeguarding the validity, reliability, and ethical integrity of the study. The outcomes of the statistical comparison employed to ascertain the equivalence between the experimental and control groups are detailed in the preceding Table 4. Figure 2 illustrates the influence of formative assessment intervention on learner achievement. The implementation of formative assessment intervention seemed to positively affect learners' academic performance.

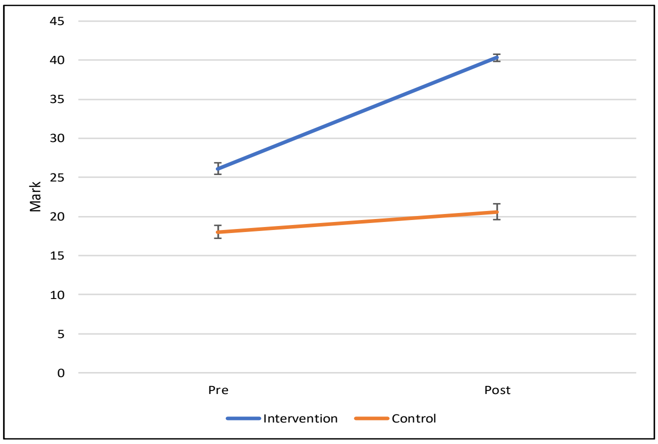

***Figure 2.** The effect of formative assessment intervention on learners' achievement (n=175)*

Table 5 provides a comparison of the means after the implementation of the intervention between the experimental and control groups. Overall, these results suggest that both groups experienced improvements in academic achievement after the intervention. However, the experimental group, which received the formative assessment intervention, demonstrated significantly higher mean scores compared to the control group, highlighting the effectiveness of the intervention in enhancing learners' performance.

***Table 5**. Comparison of the means after the implementation of the intervention (n=175)*

Group	Mean	Range	Sd	t	P-Value
Experimental	40.32	50-26=24	5.06	17.419	P=0.000
Control	20.60	40-8=32	7.79		

Assessing the efficacy of the intervention

Figure 2 depicted above showcases the outcomes of both the experimental and control groups following three weeks of instruction and application of the intervention. As per Figure 2, the experimental group exhibited notably superior performance, with a mean score of 40.32% on the post-test, compared to the control group's mean score of 20.60% on the post-test, indicating a difference of 19.72%. Both groups demonstrated significant improvements compared to their respective baseline scores. However, it's worth highlighting that the experimental group outperformed the control group by nearly double the score. This suggests that although both groups started with a relatively small initial difference (24.6% for the experimental group and 18.04% for the control group, a disparity of 6.56%), they ended up significantly divergent from each other following the implementation of the formative assessment intervention in the experimental group. Table 5 provided above compares the post-test means of the two groups to ascertain the statistical significance of the observed variances. According to the findings in Table 5, the hypothesis that 'learners exposed to formative assessment intervention perform statistically higher than those in the normal classroom without intervention' can be validated. Therefore, based on these outcomes, it can be concluded that formative assessment intervention practices are considerably more effective than conventional instruction in teaching physical science.

Table 6 provides insights into the effectiveness of formative assessment intervention practices, based on a total sample size of 175 participants. Before the intervention, the experimental group attained a mean score of 26.4%, contrasting with the control group's score of 18.04%. After the intervention's implementation, the experimental group's mean score rose to 40.32%, marking a 13.92% increase, while the control group achieved a post-test mean score of 20.60%, reflecting a slight increase of 2.56%. There are several reasons for the slight improvement that was seen after three weeks of teaching a difficult concept like electricity and magnetism, even though preliminary tests revealed little prior understanding. First, the subject matter is difficult by nature, necessitating not only conceptual knowledge but also the application of mathematical models and problem-solving strategies. The abstract ideas of electricity and magnetism, such as electric fields, electromagnetic forces, and circuits, can be challenging for learners to fully understand quickly, particularly if the teaching does not actively engage them or relate the material to real-world situations. Both the pre-test and post-test comparisons yielded p-values of 0.000, indicating that the observed outcomes are highly improbable to have arisen by chance alone. These findings suggest that the formative assessment intervention practices had a significant and positive impact on learner achievement. The Experimental group consistently outperformed the Control group both before and after the intervention, with statistically significant differences in mean scores observed at both time points.

Table 6. *The effectiveness of formative assessment intervention practices (n=175)*

Time	Comparison	Means	p-value
Before	**Experimental vs. Control**	26.4 vs 18,04	P=0.000
After	**Experimental vs. Control**	40.32 vs 20.60	P=0.000

Discussion

The outcomes of this study indicate that Physical Sciences learners who were exposed to formative assessment intervention outperformed their counterparts in the control groups who received conventional instruction, such as demonstration without interactive learning. The substantial impact observed from the implementation of key formative assessment strategies in this study can be credited to the dedication, commitment, and hard work of three teachers who made concerted efforts to integrate formative assessment intervention practices into their teaching. This endeavour entailed significant adjustments in their accustomed teaching methods and the learning approaches familiar to their students. However, the results reflect the teachers' willingness to explore innovative approaches and the learners' ability to adapt and embrace the new learning methods, ultimately leading to improved performance. Their combined efforts and resilience resulted in significant learning advancements, surpassing the performance levels of learners who received traditional instruction (control group).

This achievement is noteworthy within the framework of the four attributes of formative assessment practices applied to the experimental group. These practices necessitated a shift in classroom assessment approaches, encompassing four key elements: clearly articulating learning objectives and success criteria, fostering effective dialogue and inquiry, providing constructive feedback to propel learners forward, and enhancing the quality of assessment and record-keeping, including self and peer assessment to activate learners as instructional resources for one another (Ozan & Kincal, 2018).

The findings of this study align with those reported by scholars such as Hayward & Spencer (2010), who attribute positive outcomes to the implementation of formative assessment practices. Such practices encourage teachers and learners to gain a clearer understanding of learning objectives, pathways to achievement, and the criteria for successful attainment in teaching and learning. For example, a study conducted by Dayal (2021) highlighted participants' acknowledgment of formative assessment practices as effective interventions in enhancing learners' achievement of intended learning outcomes. Thus, the model employed in this study to apply formative assessment intervention practices has proven to be highly effective. However, it is important to recognise that the transition from conventional instruction, as termed in this study, to the implementation of practices aligned with formative assessment was not without challenges. Physical Sciences teachers and learners faced the task of assimilating and comprehending the expectations associated with these practices. Nonetheless, once accustomed to the practices, the teaching and learning of Physical Sciences became more enjoyable, productive, and purposeful, leading to the achievement of desired outcomes.

Recommendations arising from the study

Based on the findings of this study, several recommendations are outlined to further enhance academic performance in Physical Sciences:

Encourage continuous professional development for teachers to familiarise with effective formative assessment practices and provide support for their implementation in the classroom.

Promote collaborative learning environments where learners actively engage with formative assessment practices, including peer assessment and self-assessment, to enhance their understanding of Physical Sciences concepts.

Advocate for policy changes at the institutional level to prioritize the integration of formative assessment practices into curriculum development and instructional planning processes.

Providing teachers with individualized support can be a highly effective recommendation if it includes targeted professional development, mentoring, regular classroom observations with feedback, and the integration of formative assessments to enhance their teaching practices and address learners' learning needs.

By implementing these recommendations, educators and policymakers can create more supportive and effective learning environments that promote academic excellence in Physical Sciences through the incorporation of formative assessment strategies into teaching and learning approaches.

Conclusion

The study underscores the significant impact of integrating formative assessment strategies into teaching and learning practices in the Physical Sciences classroom. The findings reveal that learners who were exposed to formative assessment interventions performed significantly better academically compared to those who received traditional instruction. This highlights the effectiveness of formative assessment practices in enhancing learners' achievement in Physical Sciences. The study's results demonstrate that the implementation of formative assessment practices, including clear articulation of learning objectives, effective dialogue and inquiry, constructive feedback provision, and self and peer assessment, led to substantial improvements in learner performance. The dedication and commitment of teachers to adapt their instructional approaches and learners' willingness to engage with new learning methods were crucial factors contributing to the success of the intervention.

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References

Al Tayib Umer, A. M., & Ameen, A. A. (2021). The Effect of Formative Evaluation on Students' Achievement In English For Specific Purposes (A Case Study Of Preparatory Year Students At Umm-Al-Qura University). World Journal of English Language, 11(2), 107–107.

Andrade, H. L. (2019). A critical review of research on student self-assessment. *Frontiers in Education*, 4, Article 87. https://doi.org/10.3389/feduc.2019.00087

Black, P., & Wiliam, D. (2018). Classroom assessment and pedagogy. Assessment in Education: *Principles, Policy and Practice*, 25(6), 551–575. https://doi.org/10.1080/0969594X.2018.1441807

Braund, H., & DeLuca, C. (2018). Elementary students as active agents in their learning: An empirical study of the connections between assessment practices and student metacognition. *Australian Educational Researcher*, 45(1), 65–85. https://doi.org/10.1007/s13384-018-0265-z

Chen, Z., Jiao, J., & Hu, K. (2021). Formative assessment as an online instruction intervention: Student engagement, outcomes, and perceptions. *International Journal of Distance Education Technologies*, 19(1), 50–65. https://doi.org/10.4018/IJDET.20210101.oa1

Csapó, B., & Molnár, G. (2019). Online diagnostic assessment in support of personalized teaching and learning: The eDia system. *Frontiers in Psychology*, 10, Article 1522. https://doi.org/10.3389/fpsyg.2019.01522

Dalby, D., & Swan, M. (2019). Using digital technology to enhance formative assessment in mathematics classrooms. British Journal of Educational Technology, 50(2), 832–845. https://doi.org/10.1111/bjet.12606

Dayal, H. (2021). How teachers use formative assessment strategies during teaching: Evidence from the classroom. *Australian Journal of Teacher Education*, 46(7). https://doi.org/10.14221/ajte.2021v46n7.1

de Aguiar, V., Zhao, Y., Ficek, B. N., Webster, K., Rofes, A., Wendt, H., Frangakis, C., Caffo, B., Hillis, A. E., Rapp, B., & Tsapkini, K. (2020). Cognitive and language performance predicts effects of spelling intervention and tDCS in Primary Progressive Aphasia. *Cortex*, 124, 66–84. https://doi.org/10.1016/j.cortex.2019.11.001

Ganajová, M., Sotáková, I., Lukáč, S., Ješková, Z., Jurková, V., & Orosová, R. (2021). Formative assessment as a tool to enhance the development of inquiry. *Journal of Baltic Science Education*, 20(2), 204–222. https://doi.org/10.33225/jbse/21.20.204

Grob, R., Holmeier, M., & Labudde, P. (2017). Formative assessment to support students' competencies in inquiry-based science education. *Interdisciplinary Journal of Problem-Based Learning*, 11(2), Article 1673. https://doi.org/10.7771/1541-5015.1673

Harlen, W. (2006). On the relationship between assessment for formative and summative purposes. In J. Gardner (Ed.), Assessment and learning (pp. 61–80). London: Sage.

Hayward, L., & Spencer, E. (2010). The complexities of change: Formative assessment in Scotland. *Curriculum Journal*, 21(2), 161–177. https://doi.org/10.1080/09585176.2010.480827

Hotaman, D. (2020). The effect of formative assessment on the academic achievement levels of prospective teachers. *Journal of Curriculum and Teaching*, 9(3), 33–44. https://doi.org/10.5430/jct.v9n3p33

Jean de Dieu, H., & Zhou, K. (2021). Physical literacy assessment tools: A systematic literature review for why, what, who, and how. *International Journal of Environmental Research and Public Health*, 18(15), Article 7954. https://doi.org/10.3390/ijerph18157954

Kyaruzi, F., Strijbos, J. W., Ufer, S., & Brown, G. T. L. (2018). Teacher AfL perceptions and feedback practices in mathematics education among secondary schools in Tanzania. *Studies in Educational Evaluation*, 59, 1-9. https://doi.org/10.1016/j.stueduc.2018.01.004

Linn, Z., Tashiro, Y., Morio, K., & Hori, H. (2022). Peer evaluations of group work in different years of medical school and academic achievement: How are they related? *BMC Medical Education*, 22, Article 102. https://doi.org/10.1186/s12909-022-03165-5

Lipnevich, A. A., & Panadero, E. (2021). A review of feedback models and theories: Descriptions, definitions, and conclusions. *Frontiers in Education*, 6, Article 720195.

https://doi.org/10.3389/feduc.2021.720195

Malone, T. (2021). Effective formative assessment strategies contribute positively to the work-readiness of new graduates in higher education. *Scope*, 10, 54–61. https://doi.org/10.34074/scop.4010001

Mngomezulu, H., Mkhize, T. F., & Nhlumayo, B. S. (2024). The role of formative feedback in teaching and learning: Grade 10 Physical Sciences teachers' perspectives. *Interdisciplinary Journal of Education Research*, *6*, 1-12.

Ozan, C., & Kıncal, R. Y. (2018). The effects of formative assessment on academic achievement, attitudes toward the lesson, and self-regulation skills. *Educational Sciences: Theory & Practice*, 18(1), 85–118. https://doi.org/10.12738/estp.2018.1.0216

Panadero, E., Broadbent, J., Boud, D., & Lodge, J. M. (2019). Using formative assessment to influence self- and co-regulated learning: The role of evaluative judgement. European *Journal of Psychology of Education*, 34(3), 535–557. https://doi.org/10.1007/s10212-018-0407-8

Pascoe, M. C., Hetrick, S. E., & Parker, A. G. (2020). The impact of stress on students in secondary school and higher education. *International Journal of Adolescence and Youth*, 25(1), 104–112. https://doi.org/10.1080/02673843.2019.1596823

Patra, I., Alazemi, A., Al-Jamal, D., & Gheisari, A. (2022). The effectiveness of teachers' written and verbal corrective feedback (CF) during formative assessment (FA) on male language learners' academic anxiety (AA), academic performance (AP), and attitude toward learning (ATL). *Language Testing in Asia*, 12, Article 19. https://doi.org/10.1186/s40468-022-00169-2

Sancho-Zamora, R., Hernández-perlines, F., Peña-garcía, I., & Gutiérrez-broncano, S. (2022). The impact of absorptive capacity on innovation: The mediating role of organizational learning. *International Journal of Environmental Research and Public Health*, 19(2), Article 19020842. https://doi.org/10.3390/ijerph19020842

Selvaraj, A. M., & Azman, H. (2020). Reframing the effectiveness of feedback in improving teaching and learning achievement. *International Journal of Evaluation and Research in Education*, 9(4), 1055–1062. https://doi.org/10.11591/ijere.v9i4.20654

Sujito, Pratiwi, H. Y., Soewono, E., Suhandi, A., & Liliasari, S. (2021). Views and practices of mathematical method for physics lecture at pre-service physics teachers. *Journal of Physics: Conference Series*, 1806, Article 012001. https://doi.org/10.1088/1742-6596/1806/1/012001

Taherdoost, H. (2016). Validity and Reliability of the Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research. *International Journal of Academic Research Management* (IJARM). Hal-02546799.

Treve, M. (2021). English for academic purposes (EAP) lecturers' perceptions of formative assessment integration in the Thai EAP context. *Journal of Language and Linguistic Studies*, 17(2), 1096–1113. https://doi.org/10.52462/jlls.77

Thyer, B. A. (2012). Quasi-experimental research designs. Oxford University Press, Inc.

Yan, Z., & Brown, T. L. (2017). A cyclical self-assessment process: Towards a model of how students engage in self-assessment. *Assessment & Evaluation in Higher Education*, 42(8), 1247–1262. http://doi.org/10.1080/02602938.2016.1260091

Zulliger, S., Buholzer, A., & Ruelmann, M. (2022). Observed quality of formative peer and self-assessment in everyday mathematics teaching and its effects on student performance. *European Journal of Educational Research*, 11(2), 663–680. https://doi.org/10.12973/eu-jer.11.2.663