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META-ANALYSIS OF THE EFFECT OF FORMATIVE ASSESSMENT ON STUDENTS' ACADEMIC ACHIEVEMENT IN SCIENCE SUBJECTS IN NIGERIA

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Abstract

The role of formative assessment in enhancing academic achievement, especially in science subjects, has been widely acknowledged, but the magnitude of its effect remains a subject of interest. This study conducted a meta-analysis to examine the effect of formative assessment on students' academic achievement in science subjects in Nigeria by synthesizing findings from empirical studies. To guide the study, four research questions were answered and one hypothesis was tested at the 0.05 level of significance. The study employed an ex post facto research design. The population of the study comprised all published empirical research conducted in Nigeria between 2010 and 2024 that investigated the effects of formative assessment on students' academic achievement in science subjects. A comprehensive search and screening process yielded 30 studies that met the inclusion criteria and therefore constituted the sample for the meta-analysis. Relevant data were extracted from the sampled studies and analyzed to determine the effect sizes. The data were analyzed using statistical procedures such as the Standardized Mean Difference (SMD) effect size (Cohen's *d*), bubble plots, forest plots, and t-tests. The findings revealed a statistically significant positive effect of formative assessment on students' academic performance in science subjects, with a mean effect size of 2.351. Based on the findings, the study concludes that formative assessment is a powerful pedagogical tool for enhancing achievement in science subjects in Nigeria and recommends its use in teaching science.

Keywords: Formative Assessment, Meta-Analysis, Academic Achievement, Sciences, Subjective, Innovative Assessment

1.1 Introduction

The role of science in the development of society is indispensable. From healthcare to agriculture to communication to transportation, science influences nearly every aspect of human life and continues to refine how society functions. As societies evolve and confront new

challenges, science continues to shape how people live, work, and interact with their environments. Defined as a dynamic human activity, science is an exciting and satisfying enterprise that requires creativity, skill and insight to understand the workings of our world (Okoli, 2024). Through systematic inquiry and evidence-based reasoning, science provides solutions to problems and opens new pathways for advancement. Given its transformative power, the importance of building a strong foundation in science education cannot be overstated. Science education equips learners with essential knowledge, fosters critical and analytical thinking, and nurtures the ability to solve real-world problems. It prepares individuals to participate meaningfully in societal growth and to contribute to innovations that promote sustainable development. Recognizing this, the National Policy on Education (FRN, 2013) emphasizes that science education must focus on the teaching and learning of science processes, principles and practical skills. This approach ensures that learners are not only knowledgeable but also capable of applying scientific thinking to real-world challenges.

Improving students' achievement in science remains a global priority, driven by the growing need for scientific literacy and STEM-related competencies. Formative assessment has been widely advocated as a means of enhancing student learning outcomes. According to Olagunju (2015), formative assessment is a strategy designed to identify learners' learning difficulties with a view to providing remedial measures to enhance the achievement of the majority of students. Formative assessment is expected to support learning by clarifying expectations, identifying gaps, and guiding learners toward improved performance. Several studies have examined the effects of formative assessment strategies on students' academic achievement in science subjects in Nigeria. The results of those studies vary in their effect sizes. This variation in the effects of formative assessment on students' achievement in science subjects may depend on how formative assessment is conceptualized. Bennet (2021), in his critical review of formative assessment, concluded that 'formative assessment' does not yet represent a well-defined set of practices and the effects should be expected to vary widely from one implementation, context, instructional design, assessment mechanism, and student population to another. Baird *et al.* (2014) described several common conceptualizations of formative assessment. In their description, one approach views formative assessment as a process where teachers evaluate students' learning to provide feedback or adjust instructional activities to better address students' needs.

Another approach focuses on students as self-regulated learners who use self-assessment to guide their actions and reach their learning objectives. Another approach combines these two approaches into a cohesive framework. To address issues related to the conceptualization and implementation of formative assessment and to reach consensus on its effects, a systematic, quantitative synthesis of previous studies is needed. This approach of integrating findings from multiple studies would offer a comprehensive perspective on the effect of formative assessment on students' academic achievement in science subjects in Nigeria. One technique for integrating the results of previous studies that addressed similar research questions and/or hypotheses is meta-analysis. A meta-analysis provides a robust statistical approach for integrating findings across multiple studies and determining an overall effect size. Ugwuanyi (2015) defined meta-analysis as the study of a large body of studies using statistical procedures to integrate, synthesize and make

sense of them. Irrespective of the size and the diversity of the research findings in a study, meta-analysis can integrate them to assess the magnitude and direction of these findings. This study, therefore, seeks to determine the aggregated effect of formative assessment on students' academic achievement in science subjects in Nigeria over a 15-year period (2010-2025).

1.2 Purpose of the Study

The purpose of this study was to integrate and analyze previous research on the effects of formative assessment on students' academic achievement in science subjects through a meta-analysis. Specifically, the study sought to:

1. Determine the magnitude of the effect size for each of the available empirical study conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria.
2. Determine the mean effect size of empirical studies conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria.
3. Visualize the contribution of each study conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria to the overall effect size using a bubble plot.
4. Visualize the effect size of the empirical studies conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria using a forest plot.

1.3 Research Questions

The following research questions were raised to guide this study.

1. What is the magnitude of the effect size for each of the available empirical studies conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria?
2. What is the mean effect size of the available empirical studies conducted between 2010 and 2024on the effect of formative assessment on students' academic achievement in science subjects in Nigeria?
3. What is the contribution of each study conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria to the overall effect size using the bubble plot?
4. What is the forest plot of the available empirical studies conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria?

1.4 Hypothesis

The following null hypothesis was tested at a 0.05 level of significance.

1. The mean effect size of the available empirical studies conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria is not significant

2. Method

The study is a meta-analytic study that adopted an ex post facto research design. This is considered appropriate as the study sought to establish a cause-and-effect relationship between the independent and dependent variables without experimental manipulations. The study was carried out in Nigeria, and the population comprised all published research findings on the effect of formative assessment on students' academic achievement in science subjects in Nigeria between 2010 and 2024. A sample of 30 published research findings was selected for the study using the purposive sampling technique, and relevant data were extracted from each study using a pro forma instrument adapted from Odo (2019). The data obtained were analyzed using the standardized mean difference (SMD) effect size (Cohen's *d)*

Search Strategy

Electronic databases such as Google Scholar, advanced Google search, PsycINFO, ERIC, Scopus, African Journal Online (AJOL), and ProQuest were comprehensively searched to identify studies that met the eligibility criteria, using carefully chosen keywords and Boolean operators to refine the search. The ancestry approach of data collection was also used to identify relevant studies by examining the references or citations in key articles to help uncover related studies that may not have appeared in initial database searches. The searched empirical works were screened by reviewing titles and abstracts to identify potentially relevant studies. The studies that passed this initial screening were subjected to a thorough full-text screening to ensure they met all the inclusion criteria, and the EXCEL spreadsheet was used to record the included studies.

Inclusion Criteria

The pre-determined inclusion criteria of empirical works used for the study include:

1. Studies that used a true experimental or quasi-experimental design with a control and treatment group, and included formative assessment interventions.
2. Studies that measured learning outcomes in science subjects such as Physics, Chemistry, Biology, Basic Science, Mathematics and Statistics.
3. Studies carried out at the secondary and tertiary education levels.
4. Studies that were carried out in Nigeria.
5. Studies published in the literature between 2010 and 2024.
6. Studies with Sufficient statistical data to compute effect sizes.

3. Results and Discussion

Research Question 1: What is the magnitude of effect size for each of the studies that examined the effect of formative assessment on students' academic achievement in science subjects Nigeria?

Table 1: Magnitude of Effect Size for Each of the Studies that Examined the Effect of Formative Assessment on Students' Academic Achievement in Science Subjects in Nigeria

Researcher(s)	Effect Size	Std. Error	Z	Sig. (2-tailed)	95% Confidence Interval Lower	Upper
Orheruata and Oyakhirome 2019	3.567	.3599	9.912	<.001	2.862	4.273
Moyosore, O. A 2015	2.271	.2342	9.700	<.001	1.812	2.730
Ajogbeje, O.j 2013	2.983	.2478	12.041	<.001	2.498	3.469
Ugodulunwa and Uzoamka 2015	2.665	.3072	8.674	<.001	2.063	3.267
Adekunle O. S 2021	4.175	.3283	12.718	<.001	3.532	4.819
Aduloju et al 2018	1.103	.2875	3.838	<.001	.540	1.667
Esomonu and Ikeanumba 2021	2.522	.1752	14.388	<.001	2.178	2.865
Agu, M,C 2021	1.533	.2937	5.221	<.001	.958	2.109
Ojugo et al 2013	2.355	.3360	7.009	<.001	1.696	3.013
Ejirohene N. O 2020	2.490	.3331	7.476	<.001	1.837	3.143
Okoye eta l 2015	.133	.2226	.597	.550	-.303	.569
Ofejiro B.K 2020	3.168	.3725	8.505	<.001	2.438	3.898
Onuka and Onambiro 2010	.998	.2015	4.955	<.001	.604	1.393
Ahmed, S.O 2022	4.700	.3541	13.274	<.001	4.006	5.394
Effiong K. C 2023	5.518	.3906	14.127	<.001	4.752	6.284
Galle et al 2023	.581	.2228	2.607	.009	.144	1.018
Uka and Madu 2016	.608	.2156	2.818	.005	.185	1.030
Okoli A.A 2022	.815	.2602	3.134	.002	.305	1.325
Osadieme, R.K 2011	2.014	.2241	8.985	<.001	1.574	2.453
Adewale, M.O 2013	2.783	.2675	10.403	<.001	2.259	3.308
Uwah and Amadioha 2024	3.455	.4992	6.921	<.001	2.476	4.433
Ijeh. S.O 2020	3.416	.3506	9.743	<.001	2.729	4.103
Oshodi, O.O 2024	.678	.2285	2.968	.003	.230	1.126
Awufalo and Olanyi 2023	.029	.0979	.294	.769	-.163	.221
Ukoh and Onifade 2020	1.194	.2288	5.219	<.001	.746	1.643
Ikpi, et al 2019	2.969	.1247	23.814	<.001	2.725	3.213
Agagawu, S. 2018	3.512	.3271	10.735	<.001	2.870	4.153
Onourah. M. 2011	3.098	.2967	10.440	<.001	2.516	3.679
Ebisiene, R. G 2013	2.309	.3333	6.927	<.001	1.656	2.962
Ukaha, M. O 2012	3.567	.3599	9.911	<.001	2.861	4.272

Table 1 show the effect size of the reviewed studies. In interpreting the effect size, the Standardized mean difference effect size (Cohen's d) criteria by Sugano and Mamolo (2021) was used.

- $0 \leq d \leq 0.50$ – Small effect
- $0.51 \leq d \leq 0.80$ – Medium effect

- $0.81 \leq d \leq 1.00$ – Large effect
- $d \geq 1.01$ – Strong effect (indicating a significant and practically important effect)

In the sampled literature, as shown in the result table, the effect size of two (2) studies was less than 0.5 (indicating a small effect), the effect size of three (3) studies was between 0.51 and 0.8 (indicating a medium effect) and the effect size of twenty-five (25) studies was greater than 1.01(indicating strong effect). This suggests that the formative assessment obviously promote students' learning performance in science subjects. The positive sign of the effect size of all studies reviewed suggest that the experimental group perform better than the control group. The above finding is in line with Ojugo (2013) study that reported that the breaking up of subject or course into small units makes for adequate preparation for the test by the students. Moreover, such frequent testing enables the student to get more involved and committed to the teaching-learning process thereby enhancing their performance. However, the above finding disagreed with the study of Bostrom and Palm (2023) which show that formative assessment practices do not have a significant effect on student's achievement in mathematics.

Research Question 2: What is the mean effect size for all the studies on the effect of formative assessment on students' academic achievement in science subjects in Nigeria?

Table 2: Studies on the Effect of Formative Assessment on Students' Academic Achievement in Science Subjects in Nigeria

	Effect Size (Cohen d)	Std. Error	Z	Sig. (2-tailed)	95% Confidence Interval		95% Prediction Interval[a]	
					Lower	Upper	Lower	Upper
Overall	2.351	.2511	9.362	<.001	1.859	2.843	-.449	5.151

Table 2 shows the mean effect size of the reviewed studies. Using the random-effects model, the computed mean effect size for the 30 studies was 2.351 (SE = 0.2511), as shown in Table 2. At a 0.05 confidence level, the 95% confidence interval was calculated, with limits ranging from 1.859 (lower limit) to 2.843 (upper limit).Using the guideline for interpretation of the Standardized mean difference effect size (Cohen's d) as provided by Sugano and Mamolo (2021), as earlier stated, the mean effect size for all the studies examining the effect of formative assessment on students' academic achievement in science subjects in Nigeria was both high and positive.

This indicates that, across the reviewed studies, the experimental groups performed better than the control groups.The above finding is line with Esomonu and Ikeanumba (2021) study that showed a significant effect size of formative assessment on students' academic achievement. Similar study by Ugbaja (2012) also reported that the effect size of formative assessment on students' academic achievement was statistically significant.

Research Question 3: What is the bubble plot of the effect size of the available empirical studies conducted between 2010 and 2024on the effect of formative assessment on students' academic achievement in science subjects in Nigeria?

Fig.1: A Bubble Plot of the Meta-Analysis of the Study's Effect Size

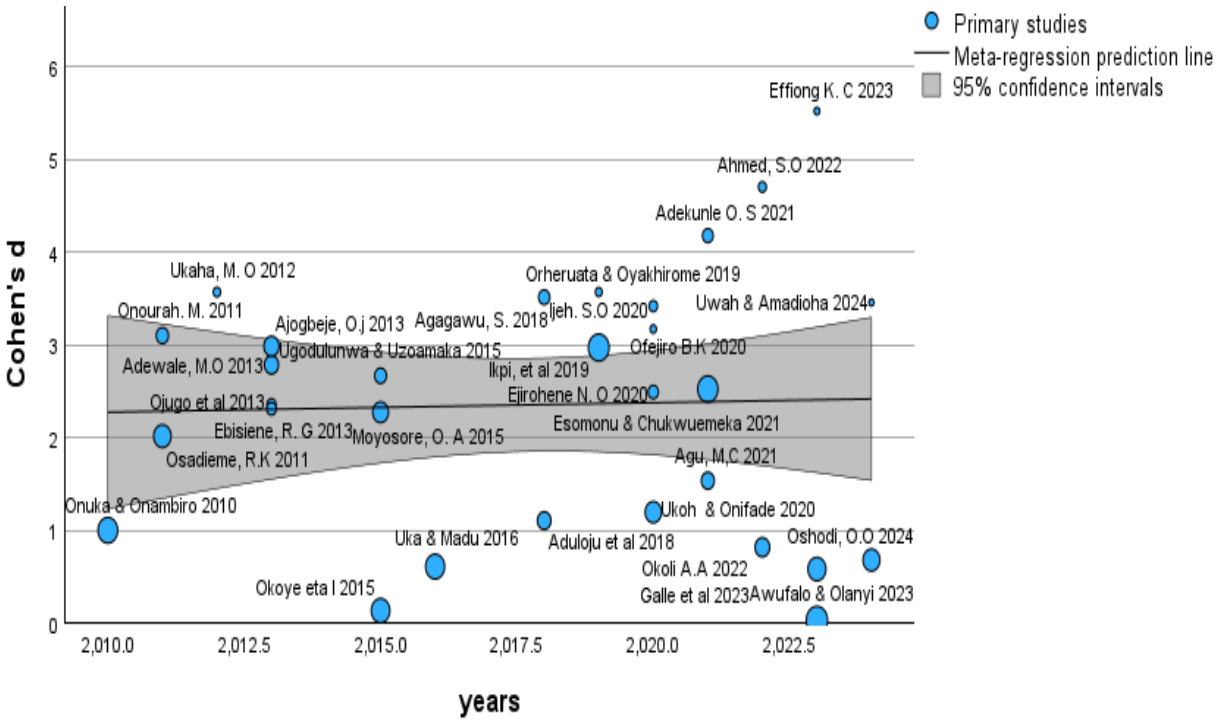

Figure 1 shows the contribution of each study to the overall effect size using the bubble plot. A bubble plot in meta-analysis visualizes the relationship between a study's effect size and a moderator variable (year of publication), with the size of the bubble representing study weight or precision. Larger bubbles represent studies that have a larger weight or are more precise in the meta-analysis, meaning they contribute more to the overall analysis. For this particular study, seventeen (17) studies have larger bubbles. These studies contribute most to the overall mean effect size of the reviewed studies.

Research Question 4: What is the forest plot of the available empirical studies conducted between 2010 and 2024 on the effect of formative assessment on students' academic achievement in science subjects in Nigeria?

Fig. 2: A Forest Plot of the Meta-Analysis of the Study's Effect Size

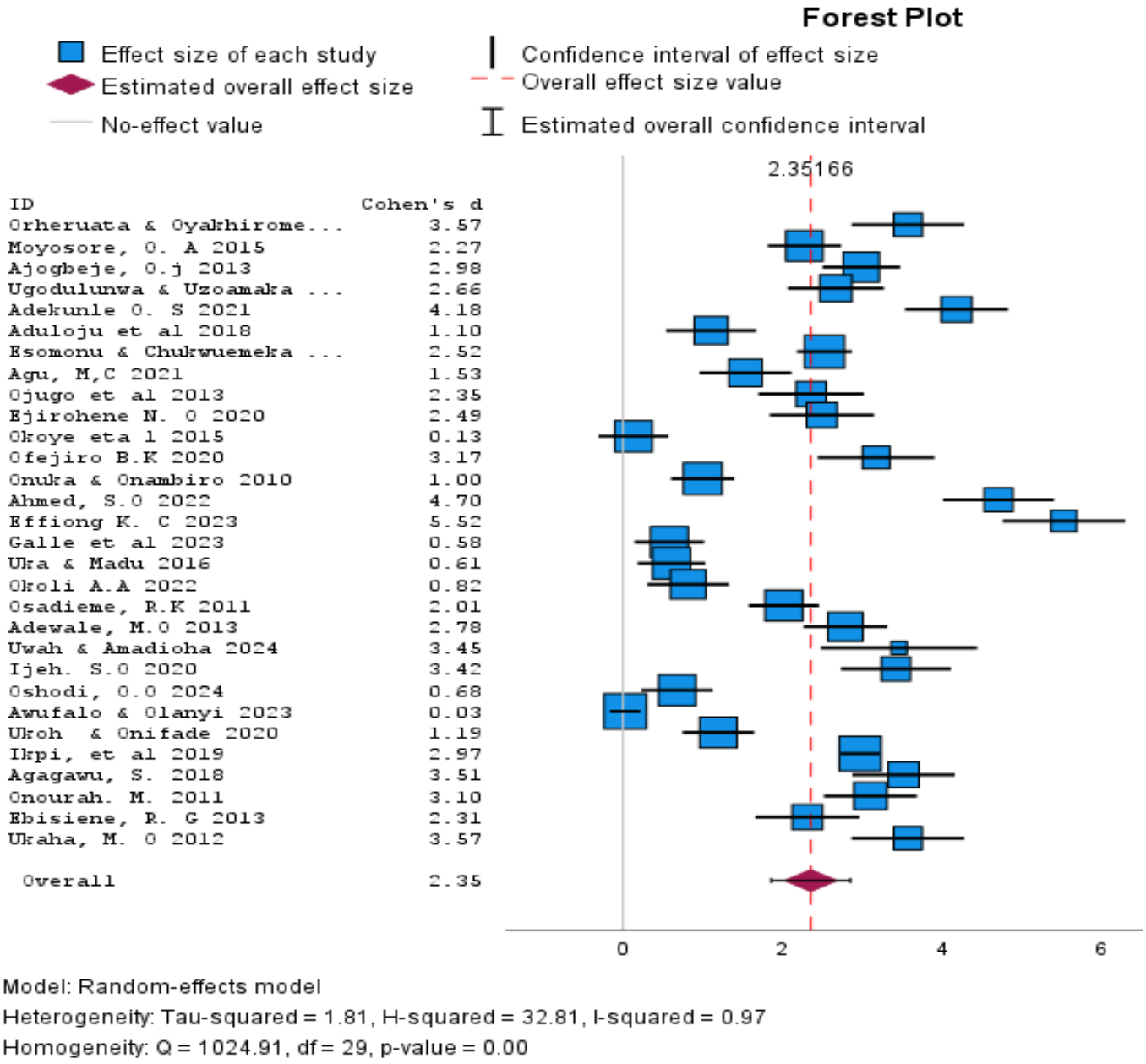

Figure 2 visualizes the effect size and confidence interval for each of the 30 studies, and the mean effect size of all studies. Each small box in the figure corresponds to the effect size of

each study, and the horizontal line through each small box signifies the confidence interval. The vertical solid line in the middle is an invalid line, indicating that the effect sizes are not statistically related to the outcome. The diamond at the bottom of the forest plot, which is crossed by a dotted line, describes the combined effect size and its confidence interval. As shown in Figure 2, most studies were on the right side of the invalid line, with statistical significance result. However, the study of Okoye et al (2015) and, Ukoh and Onifade (2020) were not statistically significant as their effect sizes cross the vertical invalid line in the middle.

Hypothesis 1: The mean effect size of studies on effect of formative assessment on students' academic achievement in science subjects is not significant.

Table 3: Test of Significance of Mean Effect Size of Studies on Effect of Formative Assessment on Students' Academic Achievement in Science Subjects

	Effect Size Estimates							
					95% Confidence Interval		95% Prediction Interval[a]	
	Effect Size	Std. Error	Z	Sig. (2-tailed)	Lower	Upper	Lower	Upper
Overall	2.351	.2511	9.362	<.001	1.859	2.843	-.449	5.151

Using the random-effects model, the computed mean effect size for 30 studies is 2.351 (SE = .2511) as seen in Table 3. This shows that the mean effect size of studies on effect of formative assessment on students' academic achievement in science subjects is significant, $Z > 1.96$, $P < .05$.

4. Conclusion

This meta-analytic investigation demonstrates that formative assessment significantly and positively influences students' academic achievement in science subjects in Nigeria. This conclusion is based on the fact that the group taught through formative assessment outperformed the group taught through conventional methods. Therefore, formative assessment is a powerful strategy in enhancing the conceptual understanding of science subjects in Nigeria.

5. Recommendations

Based on the study's findings, the following recommendations were made.

1. Education policymakers at the national and state levels should formally integrate formative assessment practices into curriculum guidelines and instructional policies.
2. Teacher professional development should be strengthened to build teachers' assessment literacy, as many science teachers lack adequate training in designing quality formative assessment tasks, interpreting students' responses, and providing actionable feedback.
3. Science teachers and school leaders should consistently apply a range of formative assessment strategies during instruction. These may include quick quizzes, exit tickets, hinge questions, concept maps, peer assessment, and targeted feedback sessions.
4. Curriculum developers and examination bodies should provide context-appropriate tools that enable the effective use of formative assessment in science. These include question banks, checklists, scoring rubrics, and model feedback statements for various science topics.

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