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Involvement of the student in their learning: Effects of formative assessment on competency development

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Abstract

The study aimed to establish the influence of formative assessment on the attainment of scientific and technological competencies in a school in Lima, Peru. We formulated and subsequently tested hypothesis of the positive impact of formative evaluation on science and technology competencies. The authors used the questionnaire associated with formative evaluative practices and to measure the development of competencies gradings of 116 second-grade high school students. It was found that formative assessment significatively influences the development of scientific and technological competencies, predicting a 0.708 increase in educational outcomes (pseudo R-squared Nagelkerke). This influence on competency attainment was examined through regression analysis. It was concluded that formative assessment, along with all its dimensions, influences the achievement of competencies related to science and technology. We recommend that its implementation in classrooms should receive greater dissemination.

Keywords: learning analysis, self-regulation, primary education, academic achievement, metacognition

INTRODUCTION

Assessment serves as the crucial link between teaching and learning. Despite its various forms, its fundamental purpose remains consistent–to gauge the extent of knowledge acquired in a session or series of sessions. As asserted by William (2010), assessment is integral to effective instruction, providing the sole means of confirming the assimilation of taught material. Formative assessment, a continuous process concurrent with learning, seeks to evaluate student performance. Hattie (2012) asserts that formative assessment caters to specific student needs, fostering improvements in educational objectives. Although there is sufficient evidence supporting the effectiveness of formative assessment, there are areas that require further research.

One of these areas is the influence of formative assessment on the achievement of scientific and technological competencies in school students. Limited research exists, particularly regarding implicit theories and the obstacles instructors face in integrating formative assessment into daily practice. Furthermore, intercultural studies analyzing the planning and execution of formative assessment in school classrooms are warranted, especially in under-researched contexts like Peru. This is one of the national contexts with the most limited research on formative assessment (Beriche & Medina, 2021; Fernández et al., 2022; Mollo & Medina, 2020).

In Peru, the prevailing assessment system fixates on grades, driven by a robust curriculum and standardized indicators (Fernández et al., 2022). This rigid structure restricts teachers from appreciating the individuality of their classrooms, resulting in a gap between students' actual knowledge and the standardized curriculum. Another aspect to consider is the nascent cognitive

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Contribution to the literature

- In Peru, the development of scientific competences is lacking. Research on the teaching and learning of sciences is scarce. This article addresses the need for increased attention to the potential of formative assessment in ensuring high-quality scientific education in line with sustainable development goal 4, which seeks to promote lifelong learning opportunities for all.
- Feedback is one of the fundamental principles of formative assessment. However, it is often a mistake to limit its impact to providing information to the teacher for hetero-evaluation. In this article, it is argued that formative evaluation is crucial for the student to develop their metacognitive ability, progressively approaching self-regulated learning.
- Basic skills in science are indispensable for the ability to understand reality. Therefore, scientific education is not exclusive to engineers or scientists. On the contrary, this article shares the conviction that scientific education is fundamental for everyone, particularly for the practice of free and productive citizenship.

tradition in initial teacher training (Vargas-Quispe et al., 2022). For the researchers, this is crucial, revealing the persistence of

(a) summative assessment,

(b) limitations in the Ministry of Education's transition efforts, and

(c) a potential lack of awareness among teachers regarding the metacognitive foundation of formative assessment.

Currently, the use of formative evaluative methodologies is sporadic, unsystematic, and dependent on the skills and knowledge of Peruvian teachers, despite available literature offering effective planning strategies. The consequences of this scenario include teachers sticking to familiar practices, potentially hindering sustained progress. Despite valuable suggestions as in Llece-Unesco (2021) for planning effective interventions, how diagnostic and formative assessment is planned, and what methods could be used (from exit cards to checklists), reality indicates that summative methods might still prevail in classrooms. Questions about explicit content will persist, leaving minimal room for in-depth student self-awareness.

Formative assessment holds substantial potential for enhancing student learning, teacher training, and the overall teaching-learning process (Cañadas, 2020; Msosa et al., 2021). Internationally, student engagement in assessment processes is a highlighted theme due to its positive impact on generic and specific competency development and higher levels of qualitative learning (Pallares et al., 2022).

Limited research exists on the predictive value of formative assessment in science and technology competency development, particularly using multinomial logistic regression. Existing formative assessment systems primarily focus on higher education, indicating an incipient developmental stage (Beriche & Medina, 2021; Fernández et al., 2022; Mollo & Medina, 2020).

In Peru, the Ministry of Education has adopted formative assessment to develop students' skills, as outlined in ministerial resolution 094-2020. The normative document establishes that the grading system focuses on qualitative aspects to support learning processes, valuing achievements, interpreting evidence for effective feedback, and determining the performance level reached by the student.

Since various activities have been carried out to enable teachers to embrace formative assessment and incorporate it into their daily performance, it is necessary to ascertain whether public school teachers are implementing it, contributing to the development and assessment of competencies, or if its implementation is hindered by a series of factors.

Martínez-Rizo (2013), for the Mexican experience, has drawn attention to the fact that it is not common to reflect on how challenging the application of formative assessment would be, despite its benefits. The fundamental cause lies in the difficulty of unlearning deeply rooted practices among teachers. This would result in interventions and programs lacking solidity to remain relevant in the medium term. Some of the main factors include the number of students per classroom, the attention often given by authorities, media, and parents to standardized summative tests. Concerning this last aspect, it seems that the result matters much more than the process.

Following Martínez-Rizo (2013), other publications have taken a similar path regarding thematic interest and have pointed out limitations for implementing and/or consolidating formative assessment: lack of standardization, improvisation in designating trainers, failure to meet set objectives (Pérez-Pino, 2017), inexperienced students not feeling fully convinced of their new role as active agents, not only in knowledge construction but also in self-evaluation and peer evaluation, and finally, formative assessment is perceived by educators and students as an overload compared to summative assessment or more conventional forms of evaluation (Atienza et al., 2016).

Therefore, the purpose of the study is to establish the influence of formative evaluation on the development of scientific competencies in a school located on the outskirts of Metropolitan Lima.

THEORETICAL FRAMEWORK

Formative & Summative Assessment

Black and William (2009) have made a crucial distinction between formative and summative assessments, centering on the concept of being "in process." Formative assessment occurs before or during the lesson, aiming to adjust teaching methods to better prepare students and understand their needs. In contrast, summative assessment invariably takes place at the end of the planned session and focuses exclusively on what has been learned during that specific period. Importantly, summative assessment does not concern itself with adapting the lesson or teaching strategies to enhance student preparation or a deeper understanding of their needs.

The authors, highlighted at the beginning of this paragraph, outline five key components of formative assessment:

1. **Sharing learning intentions & criteria for academic success:** Making clear the objectives of the learning process and the criteria by which academic success will be measured.
2. **Designing classroom discussions & learning tasks:** Crafting classroom discussions and learning tasks that provide tangible evidence of students' comprehension and understanding.
3. **Providing constructive feedback:** Offering feedback that aids students in continuing to develop their skills and understanding.
4. **Engaging students with relevant teaching resources:** Activating students with educational resources that align with their evolving educational realities.
5. **Empowering students for self-directed learning:** Preparing students to take responsibility for their own learning journey.

This differentiation underscores the dynamic and continuous nature of formative assessment, which actively contributes to the ongoing learning process, in contrast to the more conclusive and retrospective nature of summative assessment. For formative assessment, it is not enough to teach thematic content. This only makes sense if the most relevant metacognitive knowledge for mastering said content is shared with the classroom. It is therefore essential that students develop skills such as: evaluating their own work based on their own criteria and those of the teacher, developing effective study strategies that help achieve better management of time and effort, becoming aware of when knows content, what is known, what is necessary to know about a particular content.

Therefore, in this study we wish to solve the problem by answering two following questions:

1. What is the influence of formative evaluation on the progress of competencies in the area of science, technology and environment?
2. What is the influence of the six dimensions of formative evaluation on the progress of competencies in the area of science, technology and environment?

Formative Assessment Theory

This article adopts a theoretical perspective grounded in constructivism, cognitive psychology, and the contributions of Sanmartí (2021). The argumentative framework developed by Sanmartí (2021) has been chosen, encompassing the following principles:

Teaching and learning constitute a process of regulation and self-regulation. Regulation occurs when the teacher adapts their methods to the needs and difficulties encountered by the learner within and outside the classroom. Self-regulation happens as the student progressively constructs a personal system for learning, continually enhancing it. In this context, students are encouraged to be as autonomous as possible, engaging in metacognitive behaviors to facilitate their learning.

Evaluation serves the purpose of assisting students in their learning, obtaining indicators of their progress and difficulties. Additionally, it aims to accompany the student in achieving a higher level of awareness of their learning.

Teachers should create didactic situations that promote interactions beneficial for mutual regulation. Learning is not a solitary endeavor; it involves learning from and with others, exchanging ideas with peers and instructors. Metacognitive awareness is associated with students' maturity, evidenced by consciously controlling learning, managing and correcting errors, transferring learning rules to different situations, and changing their own learning behaviors.

On a parallel note, the Ministry of Education (Minedu, 2023) views formative assessment as a procedure enabling the recognition of students' learning to reinforce it during the learning process. From a cognitive perspective, formative assessment concerns the cognitive functioning of the student, specifically the cognitive strategies employed to achieve an objective. Moreover, from a socio-cultural theory perspective, as per Vygotsky (1978), it is essential to identify the zone of proximal development, including both the student's successes and potential errors.

In this research, formative assessment is defined as a process for collecting and analyzing information to make decisions. It emphasizes the regulatory nature of formative assessment in teaching and learning processes (Sanmartí, 2010). The traditional stance, where the teacher has the regulatory role is challenged. Instead, it is proposed that the teacher should provide strategies for the student to self-regulate their cognitive processes, termed by Sanmartí (2010) as formative assessment. Therefore, a crucial dimension is metacognition; assessment should serve to enhance learning and enable students to gain increasing autonomy, especially in societies deeply rooted in a grading culture.

The development of this metacognitive dimension is indispensable for students to reflect and have metacognitive control. However, metacognitive skills do not emerge spontaneously; they must be taught to students, enabling them to plan, monitor, and evaluate the deployment of their own knowledge (Pozo & Mateos, 2009). To achieve this, it is necessary to develop didactic and evaluative strategies that foster autonomous learning.

Dimensions of Formative Evaluation

Cerón-Urzua et al. (2020) proposed a six dimension evaluation framework for formative assessment practices in a classroom that will ultimately impact the academic performance of students. The dimensions are grading, proactive, interactive, metacognitive, retrospective, and adjusted. The grading dimension evaluates how teachers provide their feedback, while the proactive dimension assesses how students' potential is used by teachers. Similarly, the interactive dimension focuses on how students participate in the learning experience, and the metacognitive dimension addresses how students are involved in monitoring and reflecting on their learning processes. The retrospective dimension covers how students use feedback to improve their learning, and the adjusted dimension evaluates how teachers adapt their teaching strategies based on student performance.

It concerns the feedback provided by teachers after marking, which is then utilized formatively within the classroom (Ozan & Kincal, 2018). Regular implementation of effective feedback assists learners in evaluating their progress and enhances their efficiency.

Anticipatory dimension. This pertains to a planned evaluation that aids in consolidating learning and preventing potential errors before commencing a task (Jorba & Sanmartí, 1994). It also aims to provide students with a clear direction towards the objectives they need to accomplish, the goals of their work, and the significance of attaining them (Cerón-Urzua et al., 2020).

Interactive dimension. This process is executed comprehensively and immediately during the learning phase, with the teacher accompanying, monitoring, and collecting information to provide feedback supporting the students. The teacher assesses their progress and informs the students of failures or successes achieved, while managing errors to enhance learning (Sanmartí, 2010).

Metacognitive dimension. Internal self-regulation processes are associated with this particular dimension, where students must be mindful of their learning and the strategies they can employ to enhance their performance. Students who cultivate these self-regulatory capacities become more autonomous, construct their own knowledge, take measures to boost their performance, improve their learning efficiency and empower themselves with appropriate teaching intervention (Fernández-Río, 2023). The development of this metacognitive dimension is indispensable for students to reflect and have metacognitive control. However, metacognitive skills do not emerge spontaneously; they must be taught to students, enabling them to plan, monitor, and evaluate the deployment of their own knowledge (Pozo & Mateos, 2009). To achieve this, it is necessary to develop didactic and evaluative strategies that foster autonomous learning.

Formative retroactive evaluation dimension. This is already a clear and concise text that adheres to the principles of objectivity, comprehensibility, conventional structure, clear and objective language, format, formal register, structure, balance, precise word choice and grammatical correctness. Therefore, there is no need for improvement. This evaluation approach encourages students to engage and feel motivated, enhancing their metacognitive skills and enabling them to take an active role in their learning. Students can identify and rectify errors independently, and teachers can reflect on their practice accordingly (Anijovich & Cappelletti, 2020).

Adjusted dimension. In the context of inclusive education, this approach is designed to meet the individual needs and preferences of all students. It allows teachers to modify their teaching methods based on each student's level of achievement and specific requirements (López-Vásquez et al., 2023). It is important to note that this method should be guided by the results of a diagnostic evaluation to ensure that teaching is appropriately tailored to each student's needs.

Scientific &Technological Competencies in Peruvian School Education

Sanmartí (2021) defines competencies as intricate abilities that necessitate the utilization of varying forms of knowledge, attitudes, procedures, emotions and feelings to execute an action in a warranted and socially significant manner. These intricate performances demand proficiencies like encoding, relating, arranging, memorizing and retrieving information, coupled with metacognitive strategies that empower students to comprehend and manage their cognitive processes (Anijovich & Cappelletti, 2020). In this essay, the contribution of formative assessment in developing five fundamental competences, including written and oral communication, intellectual leadership, teamwork, creativity and innovation, and discernment and responsibility, will be discussed. These competences are deemed essential for educational progress and scientific competence. This involves the ability to convey concepts objectively by linking them to empirical evidence and applying them to the analysis of environmental data and selection of the most appropriate behaviors (Sanmartí et al., 2020).

Formative assessment challenges the prevalence of written knowledge tests among teachers. Instead, its formative nature promotes the development of competence in oral and written communication. Additionally, it encourages the use and interpretation of graphic, symbolic and mathematical information for assessment purposes. Later in this research, it is indicated that the third competency in the field of science, technology and the environment demands this practice.

The impartial assessment of a specific problem, based on a comprehensive and critical approach to information sources, constitutes a part of intellectual leadership. In order to achieve this, students refine their critical thinking and argumentative skills, problem-solving abilities, and efficiency in managing interdisciplinary knowledge. In the realm of science, technology, and the environment within the curriculum, it is anticipated that the initial competency will be enacted to a large extent.

Currently, it is extremely challenging to come across educational movements or pedagogical tendencies that disregard the importance of cooperative learning. Mediated activities, deployed through formative assessment, emphasize the ability to engage in dialogue, manage conflict, distribute and execute responsibilities and carry out collaborative assignments. In terms of the secondary skillset involved with science, technology and the environment, teamwork allows for the elucidation of the physical universe, by drawing upon previous experience and local customs.

Through the implementation of formative assessment, environmental challenges cannot be adequately resolved by just applying successful solutions in diverse socio-cultural settings. Instead, this approach encourages the development of fresh and innovative strategies for the enhancement and revitalization of the environment. As a consequence, divergent thinking, adaptability and a proactive approach to risks are essential, particularly for the third competency in the science, technology and environment domain.

It is becoming more apparent why formative assessment places emphasis on the gradual attainment of self-knowledge, self-regulation, autonomous performance, and ethical commitment, particularly for the three competences within the field of science, technology, and environment. This study measured the three competences comprising the science, technology and environment curriculum area. In the subsequent sections, we will outline each of these three competences and the skills they require:

C1. Investigates situations that can be investigated through scientific methods. Five skills are required to master this competence, including:

(a) identifying problematic situations,

(b) developing strategies to conduct research,

(c) gathering and recording data and information,

(d) analyzing data and information, and

(e) assessing and communicating findings (Minedu, 2017).

These performances should be analyzed objectively through specific and quantifiable measures. By adhering to these principles, an accurate and objective analysis of the performances can be achieved. For instance, situations should be critically examined by selecting relevant questions that can be answered with the aid of prior knowledge and reliable sources. Moreover, when depicting causal relationships between variables, it is important to differentiate those that belong to the context, including socio-demographic factors such as age and level of education. The development of concrete strategies for inquiry is contingent on the learner's ability to establish a procedure that enables intervention in the independent variable's progression and measurement of its impact on the dependent variable, while keeping the intervening variables constant. Only then can they respond to the unknown with surety.

The acquisition and documentation of data and information is made feasible through repetitive measurements aimed at reducing stochastic errors, thereby enhancing the precision of the outcomes. Demonstrable by dual or linear diagrams, the exegesis of trends or patterns, and the correlation of this information with carefully chosen sources, embody the analysis of data or information. Finally, in this particular instance, evaluating and communicating involve presenting conclusions via various channels and references (models), demonstrating the application of scientific-technological knowledge and mathematical terminology, such as probabilities, through virtual or face-to-face means.

C2. Elucidate the physical world based on comprehension of living organisms, material substances and energy, biodiversity, Earth and the universe. To attain this aptitude, one must possess two proficiencies:

(a) comprehends and utilizes information concerning living organisms, substances, and energy, biodiversity, Earth, and the cosmos and

(b) assesses the impacts of scientific and technological knowledge and labor (Minedu, 2020).

To fully analyze these performances, it is necessary to employ concrete and measurable actions. For instance, achieving a solid grasp of knowledge and its application requires adaptable performances in forging connections between different concepts and transferring them to novel contexts. This leads to the development of models of both the natural and man-made universe, which are expressed when learners clarify, illustrate, refine, compare, contextualize and generalize their knowledge. The objective evaluation of the effects arising from scientific and technological knowledge and activity necessitates articulating changes in the current state of knowledge with a critical outlook, considering empirical and scientific evidence. This contribution aims to conserve the environment and improve the quality of life.

Additionally, **C3** designs and creates technological remedies to tackle problems in their surroundings. Four skills are essential for achieving this competency: Firstly, identifying an alternative technological solution; secondly, designing the alternative technological solution; thirdly, implementing the alternative technological solution; and fourthly, evaluating and reporting on the functioning of the alternative technological solution (Minedu, 2017).

The analysis of these performances requires objective and measurable actions. As an illustration, in order to determine and develop an alternative technological solution, it is important to identify a problem based on both scientific and technological knowledge, along with local practices. This can be corresponded graphically considering the available resources; and its relevance must be evaluated to select the appropriate solution. On the contrary, implementation of the technological solution alternative needs thorough verification and validation of its parts' specifications and operation. Task completion, however, does not conclude there; communication of its operation and analysis of its potential environmental and social impact are mandatory.

LITERATURE REVIEW

Beekman et al. (2021) found a significant association between self-regulation and motivation development and formative assessment interventions that included self- and peer-assessment. Wafubwa and Csikos (2022) demonstrated better academic performance and metacognitive awareness in students exposed to formative assessment guidelines compared to those taught under conventional instruction. Kültür & Kutlu (2021) discovered that formative assessment had a favorable impact on students' academic achievements, attitudes towards mathematics, and self-expression in the classroom following metacognitive analysis. Additionally, Sotaková et al. (2020) reported that formative assessment of science abilities was more successful than a curriculum focused solely on conceptual aspects. The impact on cognitive processes pertaining to understanding, assessment, and implementation has been observed, with pupils achieving lower academic scores asserting that the majority of them experience a heightened desire to attain their educational goals.

Babincaková et al. (2020) have demonstrated the beneficial effect of formative assessment on academic performance, attributing it to the improvement of basic cognitive skills, including perception and attention, as well as complex skills such as analysis, thinking, and knowledge transfer. Similarly, Ozan and Kincal (2018) have proven that the implementation of formative assessment has a positive impact on academic performance, improved attitudes towards subjects, and advancement in self-regulation skills. Broadbent et al. (2021) evidenced progress in self-regulated learning in both a virtual setting and one that combined distance and face-to-face activities. There was an improvement in grades, as well as perceived self-efficacy, management of available time, and regulation of personal effort. An appreciable impact on self-regulation skills was observed in the study by Fraile et al. (2020) due to formative assessment and greater use of assessment criteria before the activity.

Gedikli and Buldur (2022) conducted research in Turkey to demonstrate the beneficial effects of implementing formative assessment practices in enhancing students' metacognitive knowledge, including declarative, procedural, and conditional knowledge, as well as their metacognitive regulation skills, such as planning, monitoring, and evaluation. The experimental group produced results (17.96) that reveal the positive impact of these practices when compared to the control group (mean [M]= 8.42). There is additional evidence supporting the effectiveness of formative assessment in promoting self-regulated learning in mathematics. Granberg et al. (2021) conducted an eight-month intervention implementing formative assessment in Sweden, which yielded positive results on students' self-regulated learning in mathematics.

Additionally, Meusen-Beekman et al. (2016) conducted a 27-week formative assessment intervention, resulting in observable improvements in self-regulation, motivation, and self-efficacy among primary school students. Similarly, Ismail et al. (2022) conducted a study on 72 Iranian students and discovered that after 15 sessions, both formative and summative assessments had an impact on assessed performance. However, formative assessments were significantly more effective in improving self-regulation learning skills, academic motivation, and test-taking anxiety management. In another study by Simon (2019) over 18 weeks, a study conducted in Minnesota, the United States, with a

Table 1. Mean values of formative assessment construct & its dimensions, along with standard deviations, & each correlation coefficient (ρ) with formative assessment score

	n	Mean	Standard deviation	ρ (K-S)	ρ (Rho)
Associated with outcomes	116	3.1149	.80350	<0.01	<0.05
Proactive	116	3.7443	.87957	<0.01	<0.05
Interactive	116	3.6336	.77770	<0.01	<0.05
Metacognitive	116	3.4310	.79917	<0.01	<0.05
Retroactive	116	3.6034	.79062	<0.01	<0.05
Adjusted	116	3.6782	.75621	<0.01	<0.05
Formative assessment	116	3.5374	.63513	<0.01	<0.05

sample size of 41 students, revealed no notable variances in self-regulation of learning and student motivation, notwithstanding integration of formative assessment.

MATERIALS & METHODS

This study involved 116 students, aged 13 to 14, in their second year of secondary education. Their families, falling into income brackets of $470 to $950 per month, are categorized in socioeconomic level **C** and level **D**. These students attend a public school, where teachers receive guidance from the Regional Directorate of Education, associated with the Ministry of Education. Many of their teachers also have additional jobs to cover living expenses. These students live in the Independencia District, situated in the northern part of metropolitan Lima, an area, where both emerging economic sectors and social strata with unmet economic needs coexist.

The focus of the study was on competencies in the science and technology field. In the 2022 PISA tests, these competencies showed a modest increase of four points compared to the 2018 results. However, this difference was not statistically significant. The overall performance is similar to the Latin American average, with 47.0% of students placed at level 2, considered the baseline proficiency. This indicates that their procedural knowledge is at a basic level; they can identify a research question in a simple experimental design and formulate a valid conclusion based on a set of explicit data.

To learn much more about the effect of formative evaluation on the development of science and technology competencies, the quantitative approach, non-experimental cross-sectional design and causal relationship (explanatory level) were used. The causal relationship attempts to explain a cause-effect relationship between two or more variables (Creswell & Creswell, 2018), the independent variable was formative evaluation, and the dependent variable was science and technology competencies. The sample was probabilistic of 116 students with a probability of error of 5.0% and the sampling was simple random, which is a probabilistic sampling procedure that gives each element of the target population and each possible sample of a given size, the same probability of be selected (Hernández & Mendoza, 2018) from a school in the Independencia District in Lima.

The instruments to measure the variables showed very strong reliability, according to Cronbach's alpha, a=0.894 for formative assessment and a=0.836 for science and technology competencies. The questionnaire corresponding to the independent variable structured and prepared by Cerón-Urzua et al. (2020).

A pilot test was carried out with 30 students with similar characteristics, the reliability for the formative evaluation variable was very strong, according to Cronbach's alpha a=0.910, with a KMO=0.935 and Bartlett's sphericity test <.001.

For the science and technology variable, reliability was very strong according to Cronbach's alpha α=0.895 with a KMO=0.910 and Bartlett's sphericity test <.001 indicating the suitability of the data for the construction of structures through factor analysis.

Statistics were performed with SPSS v.25 statistical software using descriptive and inferential analysis using a non-parametric test such as ordinal logistic regression that allows shaping the dependence of a polytomous ordinal response on a set of predictors.

To evaluate the goodness of fit of the logistic regression model, the R-squared of Nagelkerke statistic is calculated, the meaning of which is the explanatory power of the model (Creswell & Creswell, 2018).

RESULTS

The results, detailed in **Table 1** and **Figure 1**, reveal statistically significant and strong correlations between formative assessment and competencies in the science and technology domain, further supported by non-normality in the data distribution for formative assessment and its dimensions.

All observed correlations between formative assessment and competencies in the science and technology domain are statistically significant ($p<0.05$) and can be classified as strong, following the classification by Hernández & Mendoza (2018).

Additionally, formative assessment and its dimensions exhibit non-normality in their data (<0.05) based on the Kolmogorov-Smirnov (K-S) test for datasets larger than 50.

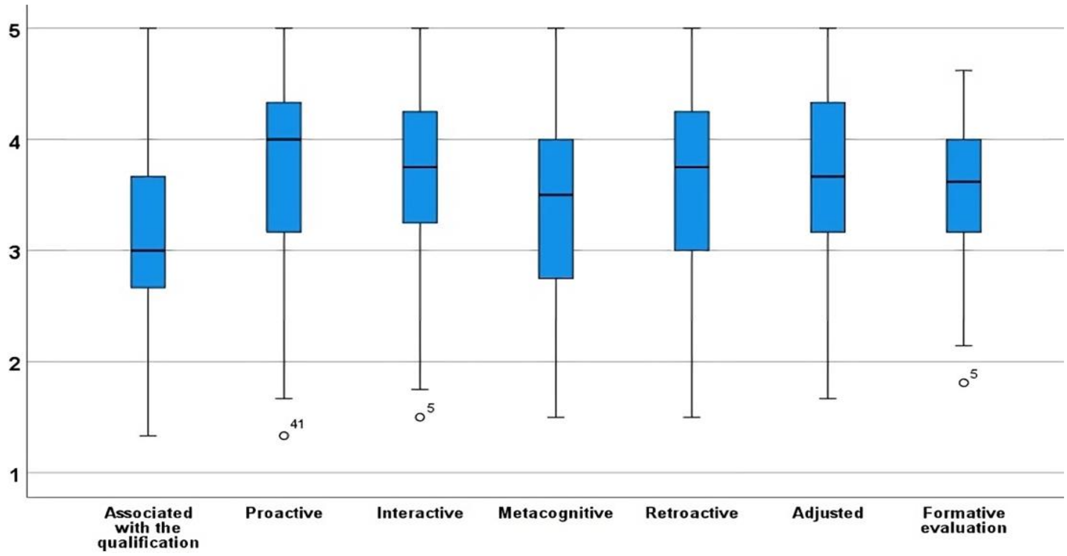

Figure 1. Box plots of data for formative assessment & its competencies (5-point rating scales used to measure constructs were adapted so that 1 represents the lowest trait level & 5 the highest) (Source: Authors' own elaboration)

Table 2. Mean values of science & technology construct & its competencies, along with standard deviations, & each correlation coefficient (ρ) to formative assessment score

	n	Mean	Standard deviation	ρ (K-S)	ρ (Rho)
Inquires	116	2.1900	.81200	<0.01	<0.05
Explains	116	2.2400	.89100	<0.01	<0.05
Designs and builds	116	1.9700	.75700	<0.01	<0.05
Science & technology competency	116	2.1200	.77100	<0.01	<0.05

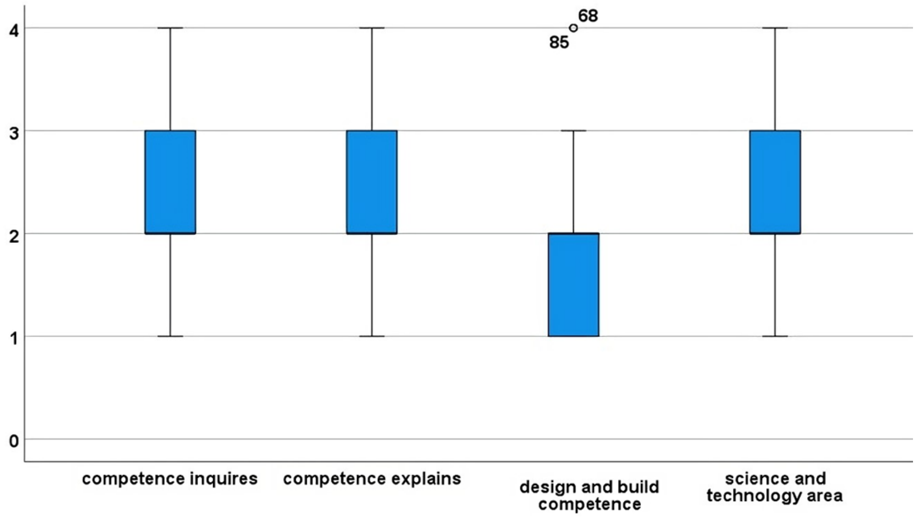

Figure 2. Box plots of data for competencies in science & technology domain (4-point rating scales employed to measure constructs were adjusted such that 1 represents the lowest trait level & 4 represents the highest) (Source: Authors' own elaboration)

Table 2 and **Figure 2** outline the descriptive statistics and correlations for science and technology, revealing strong and statistically significant connections with formative assessment. The integration of formative assessment in learning sessions proves instrumental in fostering student reflection, self-awareness, and metacognitive development, emphasizing its positive impact on the science and technology construct and competencies.

Descriptive statistics for science and technology are provided in **Table 2** and summarized in **Figure 2**. All observed correlations with formative assessment are statistically significant ($p<0.05$) and, similarly to the previous case, can be classified as strong. Presence of formative assessment in learning sessions offers students opportunity to reflect on their learning, identify strengths and areas for improvement, and receive guidance and support from teacher and their peers.

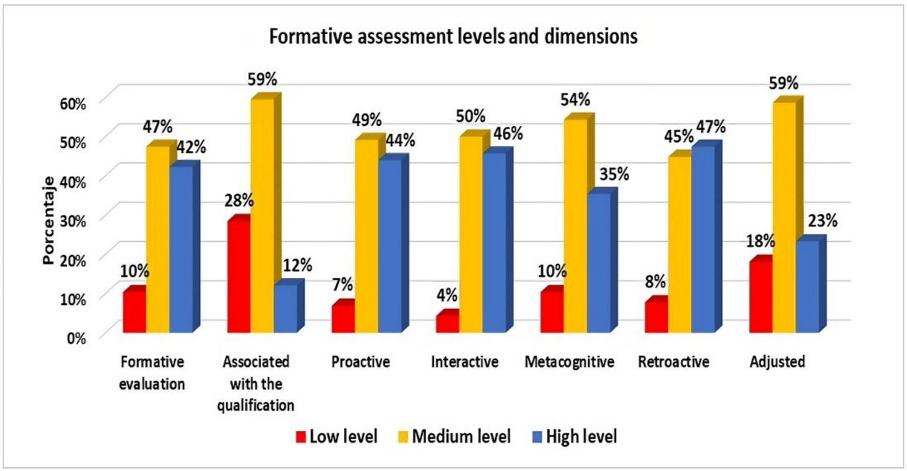

Figure 3. Levels of formative assessment & its dimensions (Source: Authors' own elaboration)

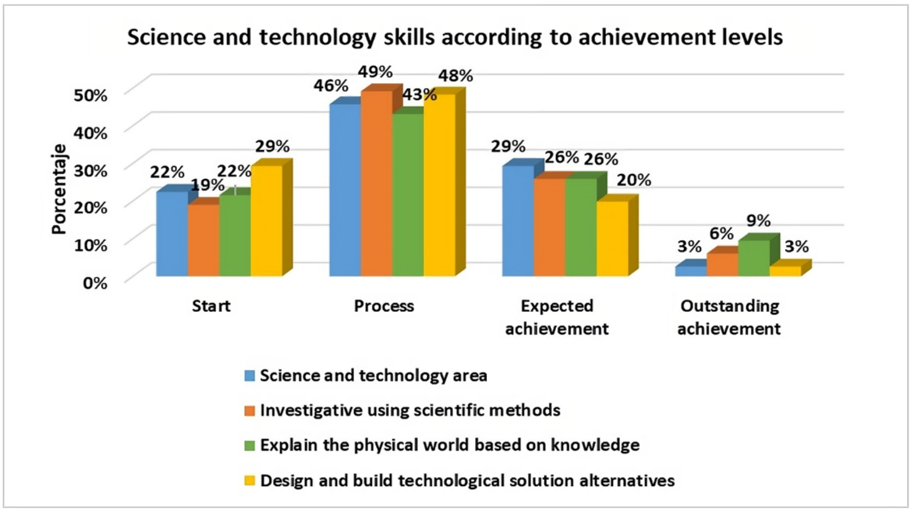

Figure 4. Levels of science & technology area & its competencies (Source: Authors' own elaboration)

This process contributes to the development of increased metacognitive awareness and the promotion of self-regulation.

In **Figure 3**, it is shown that the medium level has been predominant as formative assessment (47.0%) as well as in its dimensions: associated with grading, 59.0%; proactive, 49.0%; interactive, 54.0%; adjusted, 59.0%; except for the retroactive dimension, where it reached a high level with 47.0%. With formative assessment present in learning sessions, students have the opportunity to reflect on their own learning, identify strengths and areas for improvement, and receive guidance and support from both the teacher and their peers. This helps them develop greater metacognitive awareness and promote self-regulation.

In **Figure 4**, it is evident that the in-process level predominates both as a curriculum area itself (46.0%) and in its competencies: inquires through scientific methods at 49.0%, explains the physical world based on scientific knowledge at 43.0%, and designs and builds alternative technological solutions at 48.0%.

In **Table 1** and **Table 2**, K-S normality test shows that the formative assessment variable and its dimensions, as well as the science and technology area and its competencies, do not follow normal distribution in their data ($p<0.05$), indicating non-normal distribution. Therefore, the non-parametric multinomial logistic regression test was used, a statistical technique to predict categorical variables through predictor variables, identifying factors that influence (Hernández and Mendoza, 2018).

Throughout this study, the following hypotheses were tested:

1. Hypothesis 1 (**H1**). Formative assessment influences the science and technology area.
2. Hypothesis 2 (**H2**). Formative assessment influences the competency inquires using scientific methods.
3. Hypothesis 3 (**H3**). Formative assessment influences the competency to explains the physical world based on knowledge.

Table 3. Hypothesis test result

Hypothesis	Paths	Model-fit			Likelihood ratio			Nagelkerke
		Chi-square	df	Sig.	Chi-square	df	Sig.	
H1	Formative assessment→science & technology	117.020	6	<0.001	117.020	6	<0.001	0.708
H2	Formative assessment→inquires	58.525	6	<0.001	58.525	6	<0.001	0.437
H3	Formative assessment→explains	49.698	6	<0.001	49.698	6	<0.001	0.395
H4	Formative assessment→designs & builds	72.431	6	<0.001	72.431	6	<0.001	0.521

Note. Chi-square statistic is difference in -2 log-likelihood between final model; & reduced model & reduced model is formed by omitting an effect from final model; & null hypothesis is that all parameters of this effect are 0

Table 4. Classification table model

Hypothesis	Observed	Expected				
		Starting	In progress	Expected achievement	Outstanding achievement	Correct percentage
H1	Starting	12	13	0	0	48.0%
	In progress	0	37	18	0	67.3%
	Expected achievement	0	0	33	0	100.0%
	Outstanding achievement	0	0	3	0	0.0%
	Overall percentage	10.3%	43.1%	46.6%	0.0%	70.7%
H2	Starting	9	11	2	0	40.9%
	In progress	3	34	20	0	59.6%
	Expected achievement	0	5	25	0	83.3%
	Outstanding achievement	0	0	7	0	0.0%
	Overall percentage	10.3%	43.1%	46.6%	0.0%	58.6%
H3	Starting	9	15	0	0	37.5%
	In progress	3	48	0	0	94.1%
	Expected achievement	0	30	0	0	0.0%
	Outstanding achievement	0	11	0	0	0.0%
	Overall percentage	10.3%	89.7%	0.0%	0.0%	49.1%
H4	Starting	12	20	0	0	37.5%
	In progress	0	59	0	0	100.0%
	Expected achievement	0	22	0	0	0.0%
	Outstanding achievement	0	3	0	0	0.0%
	Overall percentage	10.3%	89.7%	0.0%	0.0%	61.2%

4. Hypothesis 4 (**H4**). Formative assessment influences the competency designs and builds alternative technological solutions.

Table 3 shows that the multinomial logistic regression model that fits the dataset of the formative assessment variable and the science and technology area with each of its dimensions (sig.<0.001). Also, the results of the likelihood ratio of the models are presented, where it is observed that the sig. <0.001 in each of them: There is statistical evidence that formative assessment influences the development of competencies in the science and technology area (sig.<0.001). Also, there is statistical evidence that formative assessment influences the competency inquires using scientific methods (sig.<0.001); Additionally, there is statistical evidence that formative assessment influences the competency explain the physical world based on knowledge (sig.<0.001). Finally, there is statistical evidence that formative assessment influences the competency designs and builds alternative technological solutions (sig.<0.001).

Table 3 presents the results of the pseudo R-squared test to analyze the degree of variability. Nagelkerke statistic was used for the decision-making process; there is statistical evidence that the explanation of the response variable for each of the models is good; therefore, it could be affirmed that formative assessment predicts a 0.708 increase in educational outcomes the science and technology area. A Nagelkerke coefficient closer to one suggests that the model has a better ability to predict the dependent variable compared to the reference model. Also, formative assessment predicts a 0.437 increase in the competency to inquire using scientific methods, showing a moderate capacity to explain the dependent variable. Furthermore, formative assessment predicts a 0.395 increase in the competency explains the physical world based on knowledge. Finally, formative assessment predicts a 0.521 increase in the competency designs and builds alternative technological solutions.

In **Table 4**, regarding formative assessment and the science and technology area, the model correctly classifies 70.7% of the information observed and predicted, which is considered an acceptable explanation value, exceeding 50.0% as recommended by specialists.

Figure 5. Flowchart of structural equation modeling for formative assessment & science & technology domain (EVAL: Evaluación formative [Formative assessment]; CYT: Área de ciencia y tecnología [Science & technology domain]; ASOC: Asociación a la calificación [Association with outcomes]; PROA, INTE, META, RETR, & AJUS: Proactive, interactive, metacognitive, retroactive, & adjusted dimensions, respectively; p1-p21: Items related to formative assessment variable; INDA, EXPL, & DISE: Inquires, explains, & designs, respectively; & e1-e25: Errors) (Source: Authors' own elaboration)

Additionally, for formative assessment and the competency inquires using scientific methods, the model correctly classifies 58.6% of the information, which is considered an acceptable explanation value. Also, for formative assessment and the competency explains the physical world based on knowledge, the model correctly classifies 49.1% of the information, which is considered an acceptable explanation value. Finally, for formative assessment and the competency designs and builds alternative technological solutions, the model correctly classifies 61.2% of the information, which is considered an acceptable explanation value.

Structural Equation Model

In **Figure 5**, the applied methodology involves utilizing the structural equation modeling approach in conjunction with the AMOS 24 software for hypothesis testing in the study. The obtained results of the indices crucial for evaluating the model fit are, as follows: TLI (Tucker-Lewis index)=0.92, CFI (comparative fit index)=0.94, and RMSEA (root mean square error of approximation)=0.040.

These indices serve as key indicators of the quality of the model fit. RMSEA, which stands for RMSEA, provides insights into the overall fit quality, where a value below 0.05 is indicative of a good fit, between 0.05 and 0.08 suggests a moderate approximation error, and a value exceeding 0.10 signals a poorly managed error.

Moreover, when both CFI and TLI are greater than 0.90, it suggests a highly satisfactory fit of the data to the researcher's model. This comprehensive approach to model evaluation ensures a nuanced understanding of the structural relationships within the formative assessment and science and technology domain, enhancing the overall reliability and validity of the study's findings.

DISCUSSION

The study findings demonstrate that formative assessment exhibits a 70.8% impact on competencies in the field of science, technology, and the environment, substantiating the general hypothesis. This outcome aligns with Beekman et al.'s (2021) research, which revealed that self-regulation and motivation development were significantly connected to self- and peer-assessment interventions as components of formative assessment.

Wafubwa and Csikos (2022) demonstrated that students instructed using formative assessment guidelines outperformed their counterparts who received conventional instruction in terms of performance and metacognitive awareness.

The results of the formative assessment independent variable show that, typically, the medium level is predominant (47.0%), followed by the high level (42.0%) and low level (10.0%), as illustrated in **Figure 1**. Comparable outcomes can be observed in the assessment of scientific investigative skills (49.0%), explanation of the physical world based on knowledge (43.0%), and development of technological solutions (48.0%), as shown in **Figure 2**.

In this study, the authors argue that formative assessment, viewed from an epistemological standpoint, offers an alternative to the measurement approach.

The instrument by Cerón-Urzua et al. (2020) is positioned as a motivating learning engine, capable of enhancing students' performance by comprehending and managing their cognitive processes (Anijovich & Cappelletti, 2020; Fraile et al., 2020; Sanmartí, 2020). Incidentally, its six dimensions were adopted for the aims of this study.

In the realm of formative assessment grading, a medium level (59.0%) was noted, trailed by a low level (28.0%) and a high level (12.0%). The contrast between the medium level and the low level proved to be significant. These outcomes propose that teachers, despite their numerous obligations, schedule time for giving personal feedback, which proves crucial in overcoming predictable resistance. Nonetheless, these findings show a moderate level of implementation.

Alongside the teacher's guidance, students themselves are encouraged to participate in the improvement process, thereby learning from the experience. The teacher provides precise and concise feedback, objectively identifying and explaining errors. Alongside the teacher's guidance, students themselves are encouraged to participate in the improvement process, thereby learning from the experience. This includes following conventional structural guidelines, ensuring clear and logical explanations, and using precise and formal language with minimal subjective insight.

Additionally, spelling and vocabulary follow British norms, with attention paid to grammatical accuracy and precise word choice. Continuing along this path is imperative as Kultur and Kutlu's (2021) research has shown that formative assessment has a positive impact on students' academic performance, attitudes towards mathematics, and their confidence to express themselves in the classroom after metacognitive analysis.

The difference between the medium (49.0%) and high (44.0%) levels was less pronounced with the proactive formative assessment dimension. This leads us to conclude that the performance of both pupils and educators meets the anticipated standards. To elaborate, the former are given timely guidance by the latter before the task is finished.

The teacher provides students with explicit instructions and encourages them to seek clarification by asking questions. This approach permits students to identify gaps in their understanding of the learning outcomes the teacher wants them to achieve. Research by Sotaková et al. (2020) found that formative assessment of science competences was more efficacious than teaching with a focus solely on conceptual aspects. The study observed the impact on cognitive processes linked to comprehension, analysis, and application. The findings showed that students with lower academic achievement reported feeling highly motivated to enhance their learning.

Concerning the interactive formative assessment dimension, the discrepancy between medium (50.0%) and high (46.0%) is only four percentage points, with low (4.0%) trailing behind. Consequently, the subsequent activities have attained a moderate to adequate ranking. The need for continual pedagogical supervision is insinuated, which assists in expediting the prompt review of the task for instant feedback. If it becomes apparent that the instructions are not being comprehended, alternative terminology or examples must be provided. Furthermore, in the event of an error with far-reaching implications, it should be presented as a salient issue for collective analysis and resolution by all classmates. A strategy is outlined here that can be applied in similar circumstances within a classroom. Babincaková et al. (2020) similarly recorded a positive effect on academic performance through the improvement of basic cognitive skills (perception, attention) and complex skills such as analysis, thinking and knowledge transfer, as a result of formative assessment. This highlights the importance of such an assessment in the academic setting.

In terms of the formative metacognitive evaluation dimension, the medium level was predominant (54.0%), with the high level following closely behind (35.0%), and the low level at 10.0%. Possible improved version in British English: It is likely that the following measures have achieved a standard level of attainment: the brief exercises are evaluated without assigning grades, as the main goal from a formative assessment perspective is to challenge the reasoning behind choices made rather than simply determining whether they are correct or incorrect. The aforementioned principles apply equally to answering both dichotomous and polytomous items, when problem-solving, or when the wording of questions allows for argumentative responses. This also extends to any reports, documents, or assessment letters. Conversely, positive academic results, improved attitudes towards subjects, and progress in self-regulation skills have been demonstrated as benefits of applying formative assessment, as proven by Ozan and Kincal (2018).

In terms of the formative feedback dimension, the high level (47.0%) was the most prevalent, with the medium (45.0%) and low (8.0%) levels following. While this is the highest level of performance attained during the analyzed process, it is only a two-point disparity from the standard level. The best approach is to provide error-based feedback, comprehend the mistake, and try to learn from it.

Teachers should share one or more pieces of information with the class to raise awareness of the error and utilize it pedagogically. In several cases, a practical procedure is presented to assist in arriving at a genuine, logical, and collective resolution. Broadbent et al. (2021) demonstrated advancements in self-regulated learning under both virtual and combined distance and face-to-face settings. The researchers observed improvements in grades, self-efficacy, time management, and personal effort regulation.

In terms of adjusted formative assessment, the majority level was medium (59.0%), followed by high (23.0%) and low (18.0%). This suggests that there is scope for enhancing personalized feedback to meet individual student needs, by providing new examples and allowing teachers to be more flexible in adapting their arguments or explanations to aid students in understanding and applying the material. This was noted by Fraile et al. (2020) who found that formative assessment had a significant effect on students' self-regulation abilities and their increased use of assessment criteria prior to carrying out the task.

A noteworthy finding of this study indicates that formative assessment impacts 43.7% of proficient inquiry methodologies, which employ scientific methods for the knowledge construction process (specific hypothesis one). This aligns with Gedikli and Buldur's (2022) research in Turkey, which showed that practicing formative assessments had favorable outcomes on students' metacognitive knowledge (declarative, procedural, and conditional) as well as their metacognitive regulation abilities, including planning, monitoring, and evaluation. The experimental group achieved results of 17.96, while the control group achieved a mean of 8.42. This study is not unique, as Granberg et al. (2021) demonstrated in Sweden that an eight-month intervention incorporating formative assessment in mathematics had favorable effects on self-regulated learning in mathematics.

Inquiry is intrinsically linked to the development of knowledge through an exploration of problems. This necessitates the use of internal resources such as curiosity and prior knowledge. In the context of science education, Sanmartí et al. (2020) contend that ideas and theories obtain significance when communicated verbally or in written form, by precisely defining the relationships using appropriate terminology. Science does not progress solely based on experimentation. The sociology of science acknowledges that scientific work advances through cooperative work in laboratories, through communication and discourse in scientific forums and publications. This approach also has a constructivist basis, as each student constructs their knowledge through constant interaction with their previous thoughts, reasoning, personal experiences, and sociocultural environment. Self-assessment and peer assessment provide students with the means to take control of their learning, resulting in interpersonal, motivational, and emotional advantages (Fraile et al., 2021; Panadero & Broadbent, 2018; Panadero et al., 2016).

The second specific hypothesis revealed that formative assessment had a 39.5% impact on competency in explaining the physical world, grounded in science-based knowledge. Meusen-Beekman et al. (2016) noted the consistency of this result with their own findings, following a 27-week formative assessment intervention that showed significant advancements in self-regulation, motivation, and self-efficacy among primary school pupils. Similarly, Ismail et al. (2022) discovered that after 15 sessions with a sample of 72 Iranian students, both formative and summative assessments had an impact on assessed performance. However, formative assessment proved significantly more effective in terms of improving self-regulated learning skills, academic motivation, and test-taking anxiety control.

Regarding students' explanations, the process they follow to arrive at a logical, well-argued, and evidence-based explanation is more crucial than whether their explanation aligns with the teacher's or textbook's viewpoint. Giving personalized and prompt feedback to the student is part of a novel error concept. Mistakes are no longer a source of shame or embarrassment, but rather an opportunity to learn and critically evaluate one's actions. It is not about assigning blame or punishment with negative grades, but rather about consolidating one's achievements. Instances of the learning process are carefully documented, not as a mere documentary desire, but with the intention of providing real and practical value to the recorded information. This objective is associated with equipping pupils with the essential means to enable them to progressively reform their circumstances to the fullest extent possible, by imparting the ability to recognize scientific situations, articulate phenomena on a scientific foundation and employ scientific evidence in their daily activities.

Finally, formative assessment influence accounts for 52.1% of the competence in designing and constructing technological solutions to solve problems (third specific hypothesis). This contrasts with Simon's (2019) findings, which showed no significant differences in students' motivation and self-regulated learning over an 18-week period with 41 Minnesota-based students, despite incorporating formative assessment. Interestingly, the author of the study identifies this discrepancy and notes:

1. The sample may not be representative, as there were only 41 students.
2. The data used for analysis were collected both at the beginning and the end of the academic semester, so it is possible that there was a decrease in motivation towards the end of the school year.
3. The sessions focused on the field of social sciences, which poses greater challenges for students in terms of following instructions and setting clear objectives compared to subjects such as mathematics or English. Additionally, it can be more difficult for students to recognize their progress over time.
4. The instructor leading the sessions did not inform the students that they were participating in a novel learning experience. Simon (2019) argues that by modifying some of the initial conditions, a repeated study would yield new findings that could enhance teaching performance guided by formative assessment.

CONCLUSIONS

Formative assessment predicts the degree of development of scientific and technological competencies in school education. The robust validation of all four hypotheses through hypothesis testing unequivocally supports the effectiveness of formative assessment in enhancing learning outcomes. The strategic embrace of a formative perspective not only serves the purpose of driving improvements in learning but also underscores the pivotal role of feedback. This becomes particularly impactful when combined with transparent performance criteria and shared improvement strategies, significantly contributing to the overall learning experience. Similarly, when assessment is approached theoretically and conceptually, the regulation and self-regulation of learning is insisted upon which is a success. However, the error lies in the fact that the responsibility for regulation is usually limited to the amount of disciplinary content and, generally, only the role of the teacher is referred to in this regard. Self-regulation, metacognitive skills, comprehensiveness and development of skills are some of the most important educational challenges of the 21st century. In this research, the co-authors subscribe to the conviction that one of the most pertinent and effective ways to address them is the implementation of formative evaluation strategies.

Implications & Limitations

In the context of evaluating the influence of formative assessment on scientific and technological competencies, this study focused on students from an institution located in the northern part of metropolitan Lima. The results yield concrete evidence of the substantial impact of the independent variable on the dependent variable, providing educational service managers with a valuable tool to fortify observed learning achievements from Ministry of Education evaluations. It's noteworthy, however, that the adoption of formative assessment may encounter varied levels of support among teaching staff and students. The establishment of effective strategies is essential to counteract inherent resistance, underscoring the role of the professional learning community.

The results of this research should also be used to acknowledge limitations. One of these is the small sample size and the fact that the students surveyed were from primary school and from an urban public school. This may make it difficult to generalize the results. However, the methodology presented in detail provides sufficient elements for the study to be replicated with larger samples and in different socio-economic and cultural contexts. Therefore, future research could include samples from private educational institutions and rural areas in order to have more representative samples of the Peruvian educational reality and more subgroups to discuss the results. Also, although our model provides some ability to explain the development of competences, there is still a significant component of variability that cannot be explained by formative assessment alone. It is important to consider the inclusion of other relevant variables (family environment, motivation, socio-economic level, among others) and to carry out a more complete analysis in order to better understand the factors that influence the development of the competences in question. It is also necessary to accompany the interpretation of the Nagelkerke coefficient with other measures of fit and the specific context before drawing definitive conclusions.

Recommendations

Based on the findings of the study, it is recommended that the strategy of formative assessment be used in the teaching and learning of other curricular areas such as communication, mathematics and social sciences. Teachers should also be offered more training courses and workshops for science, technology and environment teachers on how to use formative assessment in developing regulation (other teachers) and self-regulation (students) for more autonomous and collaborative learning. It will be interesting to see that the educational materials available also respond to the purposes of formative assessment. To enrich the quantitative findings, incorporating qualitative insights through in-depth interviews with students about their cognitive and metacognitive strategies can offer valuable supplementary information, providing a comprehensive understanding of the impact of formative assessment on the learning process.

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