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Exploring Formative Assessment Strategies in the Chemistry Classroom in Secondary School: A Systematic Literature Review (SLR)

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Abstract

Formative Assessment strategies in chemistry classrooms are important for enhancing learning, identifying misconceptions, improving student engagement, promoting metacognition, and supporting differentiation in the classroom. This research utilizes a systematic literature review (SLR) method to examine formative assessment strategies in the chemistry classroom in secondary schools. The review process follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Twenty articles were assessed using the Mixed Methods Appraisal Tool (MMAT), focusing on empirical studies published between 2019 and 2023. The article selection process utilized two databases: Scopus and Web of Science (WoS). The major findings identified four key themes related to formative assessment in the chemistry classroom; the teaching and learning approaches, assessment tools, technology and professional development within the secondary school setting. Further study recommendations include exploring diverse formative assessment methods and integrating innovative assessment tools with technology to enhance self-assessment and improve student outcomes.

Keywords*:* Formative Assessment, Chemistry Classroom, Assessment Strategies, Teaching and Learning, Secondary School

Introduction

Formative assessment, as explained by Black and Wiliam (1998), is a method implemented by teachers and students to gather evidence of student progress. This evidence is then used to make decisions about future educational strategies and learning plans. This type of assessment emphasizes a crucial aspect of education which enables instructors to facilitate student learning by discovering, understanding, and promoting their thought processes (Murray et al., 2020). Over the years, despite the practices of formative assessment have changed while innovation and models have been developed, the main objective remains to assist students in their learning (Park, 2017).

The process of formative assessment involves collecting evidence of students' learning progress, which can be used by teachers and students to make informed decisions during teaching and learning (Black & William, 2009). Educators have different strategies to evaluate students' comprehension and their learning needs at the end of the lesson. Researchers explore various strategies to enhance the use of assessment methods in the classrooms in science educational settings (Izci & Siegel, 2020). Similarly, teachers apply different methods in the classroom to provide useful, timely feedback and adjust their teaching strategy based on students' needs as the different methods or strategies will have diverse effects on the students.

In chemistry education, equipping students with skills and indispensable information to face the complexities of the 21st century is crucial. Chemistry is a tricky subject due to its complex and abstract nature to understand (Musengimana et al., 2021). Ensuring that students master the chemistry concepts in the classroom, it is important to enhance their critical thinking skills, encourage students to work collaboratively with peers and deepen their understanding of various chemical concepts. Furthermore, teachers can use different methods to interpret evidence about students' ideas and take actions to guide the learning process as formative assessment is an important tool for enhancing students' learning and understanding (Ochsen et al., 2023). Although formative assessment is identified as an important tool in the classroom, teachers often have different knowledge in applying formative assessment in practice and a lack of understanding in conducting formative assessment (Johnson et al., 2019; Yasar, 2020). The variety of tools and pedagogical approaches is considered a strategy that fulfils teachers' and students' needs to improve the teaching and learning process in the chemistry classroom. Chemistry teachers should assess students' reasoning skills and knowledge in the adoption of chemical thinking context instead of focusing on knowledge (Talanquer, 2019).

Nadiia et a, (2022) highlighted in chemistry subjects, formative assessment consists of different forms of methods and depends on many factors such as the place where the educational process, state of emotions, activity and content activities in the classroom. Therefore, to augment students' learning in the classroom, especially in chemistry, the teacher should make significant efforts to plan the strategies during formative assessment. Specifically, in the chemistry context, there is little research related to formative assessment strategies in chemistry which is discussed (Dini et al., 2020). Understanding the faced problem by the teachers is also necessary as the teachers are the main facilitator in the classroom that facilitate students learning especially in designing and planning the lesson in the classroom which brings a greater impact on students.

Research Questions

1. What strategies are used by teachers in formative assessments in chemistry classes among secondary schools?
2. How does the implementation of varied formative assessment strategies enhance student's learning in chemistry classrooms?
3. What are the challenges faced by teachers in implementing formative assessment strategies in their chemistry classrooms?

Methodology

Review Protocol

The methodology used in this SLR research is to identify relevant articles for the specific study of formative assessment in secondary school in the subject of chemistry. The strategy for selecting articles via a systematic review is through identification, screening, and determining eligibility. Moher et al (2009) highlighted the PRISMA framework will assist the researcher in reporting systematic reviews in an extensive array of research disciplines. Furthermore, this framework also will recognize some aspects and could help the researcher identify any potential bias if more information is needed for a correct appraisal of the study's validity. Based on this research, this study focuses on criteria for inclusion and exclusion in a specific study of formative assessment in chemistry subjects for secondary school. Using the PRISMA, a review of comprehension of scientific literature within a specified timeframe, and narrow to formative assessment and chemistry at the secondary school level.

Identification
This research was conducted using two major databases to optimise the probability of retrieving relevant articles: Scopus and Web of Science (WoS). Scopus, generally, is a comprehensive database encompassing over 256 academic disciplines, inclusive of education studies. Formative assessment is relatively indexed in 996 journals. The systematic review was carried out in October 2023 and involved three key stages: identification of relevant studies, screening of these studies, and determining their eligibility for inclusion. Table 1 below shows the keywords used in the research.

Table 1

Database	Keywords
Scopus	TITLE-ABS-KEY (("formative assessment" OR "formative evaluation" OR "assessment for learning" OR "assessment as learning") AND ("chemistry" OR "chemistry education" OR "chemistry subject") AND ("high school" OR "secondary school" OR "secondary education"))
WoS	TS = (("formative assessment" OR "formative evaluation" OR "assessment for learning" OR "assessment as learning") AND ("chemistry" OR "chemistry education" OR "chemistry subject") AND ("high school" OR "secondary school" OR "secondary education"))

Screening
In the screening phase, ten articles that were duplicated in both databases were eliminated, leaving 69 papers for the preliminary screening phase, inclusion and exclusion rules to access the articles. The author chose available public articles before types of the documents were seized. The articles that provide empirical data will selected. The publication of articles in English-written articles language is the third criterion. The next criterion stipulated is that articles must have been published within the preceding five years from 2019 to 2023 only. Further details regarding these inclusion and exclusion criteria can be found in the mentioned guidelines in Table 2.

Table 2

Criteria	Inclusion	Exclusion
Publication Timeline	2019-2023	2018 and before
Document Type	Articles	Proceeding, Books
Language	English	Non-English
Nature Of Study	Related to Formative Assessment, focus on chemistry subject of secondary school	Not Related to Formative assessment and general assessment also not focus on chemistry subject

Eligibility

This part involved a detailed review of the title, abstract, results, and discussion sections of the research paper. In this research selection criteria, 79 articles were subject to precise assessment. Nevertheless, because of their limited applicability from the specific focus on formative assessment in chemistry and not to science in general, a total of 42 articles were considered essential and therefore excluded.

Inclusion

After the screening process, 20 articles that met the necessary criteria were selected. The expert conducted a secondary review to avoid potential bias. To ensure all articles maintained in the final selection comply with the set standards, reassessing and affirming the inclusion or exclusion of articles was conducted based on the established criteria. The overview selected articles have been listed in Table 3.

Quality Appraisal

Quality assessment is performed to confirm that, the systematic approach and analysis of selected studies are achieved to an appropriate standard. Based on the Mixed Methods Assessment Tool (MMAT) developed by Hong et al (2018), this will facilitate the researchers to appraise mixed-methods studies within a systematic review. Before the quality assessment, two screening procedures are executed for the chosen study to employ the main criteria to align with the research design. MMAT tools optimize the pathway by highlighting crucial elements in the suitability of research questions to get sufficient data, the qualitative sufficiency of data collection in answering research questions, the consistency across qualitative data sources, data collection, analysis, and interpretation. Refer to Table 4 for assessment criteria for quality appraisal.

The full reading of each article was carried out with a centre on the methods section and analysis undertaken. Using MMAT as an assistant, the researcher critically reviewed the papers, focusing on sampling and analysis aspects. Every item was valued based on five criteria and will be included in the review if it passes at least three criteria. In the final analysis, eight articles fulfilled all the standards, five articles met at least four criteria, and seven met a minimum of three criteria.

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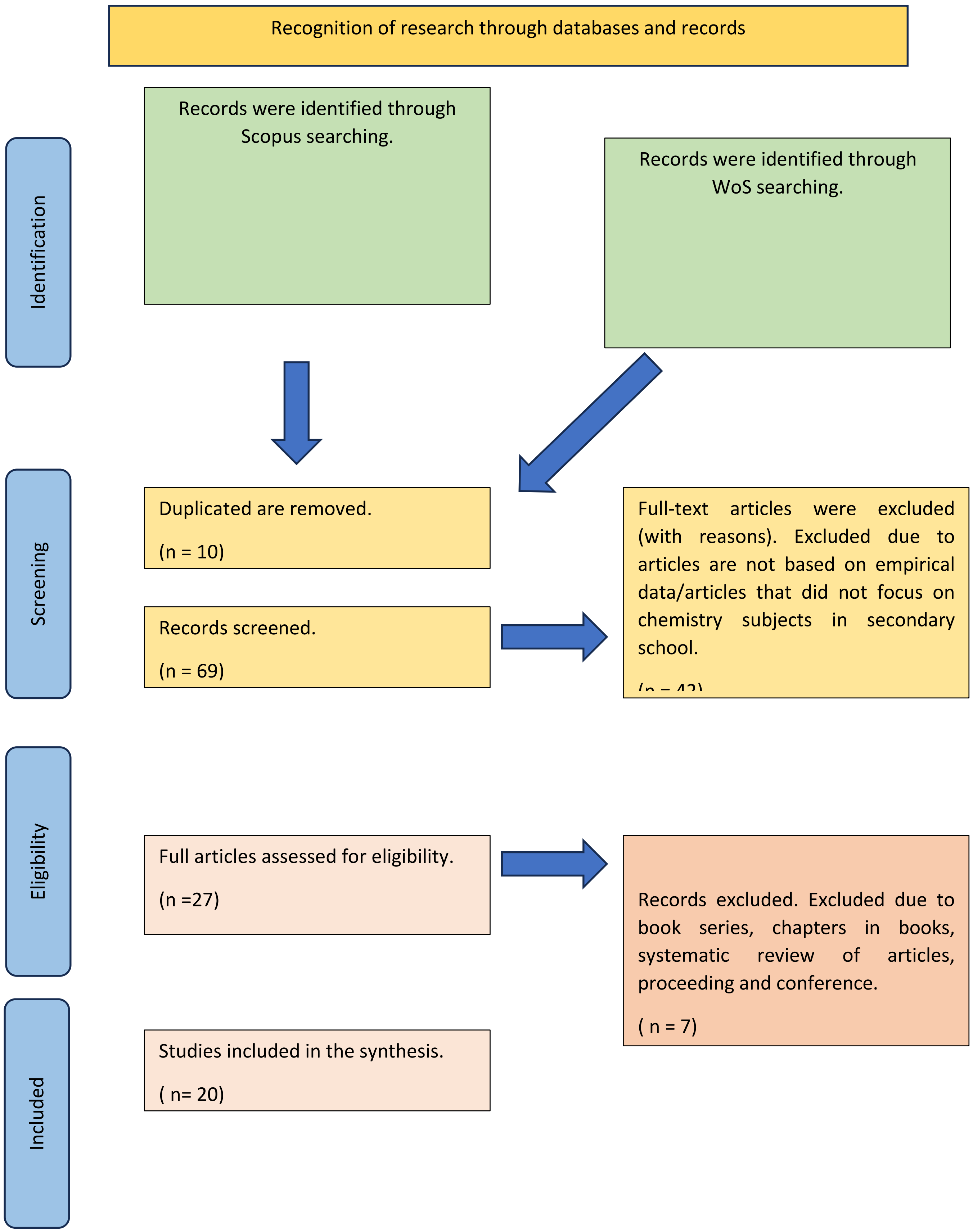

Figure 1 PRISMA flow diagram

Table 3

Num.	Authors	Research Title
1	Easa & Blonder (2022)	Development and Validation of Customized Pedagogical Kits for High School Chemistry Teaching and Learning: The Redox Reaction Example.
2	Boesdorfer & Daugherty, (2020)	Using Criteria-Based Digital Badging in High School Chemistry Units to Improve Student Learning.
3	Babinčáková et al., (2020)	Influence of Formative Assessment Classroom Technique (FACTs) on Student Outcomes in Secondary School Chemistry.
4	Abell & Sevian, (2020)	Analyzing Chemistry Teachers' Formative Assessment Practices Using a Formative Assessment Portfolio Chapter.
5	Ochsen et al,. (2023)	Interestingness is in the Eye of the Beholder: The Impact of Formative Assessment on Students' Situational Interest in Chemistry Classrooms.
6	Bernard et al., (2019)	Integration of Inquiry-Based Instruction with Formative Assessment: The Case of Experienced Chemistry Teachers.
7	Bernal-Ballen & Ladino-Ospina, (2019)	Assessment: A Suggested Strategy for Learning Chemical Equilibrium.
8	Ryan & Stieff, (2019)	Drawing for Assessing Learning Outcomes in Chemistry.
9	Orduña Picón et al., (2020)	Conceptual Profile of Substance Representing Heterogeneity of Thinking in Chemistry Classrooms.
10	Nsabayezu et al., (2022)	Rubric-Based Formative Assessment to Support Students' Learning of Organic Chemistry in Selected Secondary Schools in Rwanda: A Technology-Based Approach.
11	Yik et al., (2021)	Development of a Machine Learning-Based Tool to Evaluate Correct Use of Lewis's Acid–Base Model in Written Responses to Open-Ended Formative Assessment Items.
12	Abell & Sevian (2021)	Investigating How Teachers' Formative Assessment Practices Change Across a Year.
13	Schafer & Yezierski, (2020)	Chemistry Critical Friendships: Investigating Chemistry-Specific Discourse Within a Domain-General Discussion of Best Practices for Inquiry Assessments.
14	Vogelzang et al., (2021)	Scrum Methodology in Context-Based Secondary Chemistry Classes: Effects on Students' Achievement and Their Perceptions of Affective and Metacognitive Dimensions of Learning.
15	Babinčáková et al., (2023)	Introduction of Formative Assessment Classroom Techniques (FACTs) to School Chemistry Teaching: Teachers' Attitudes, Beliefs, and Experiences.
16	Murray et al.,(2020)	Teachers' Noticing, Interpreting, and Acting on Students' Chemical Ideas in Written Work.

17	Schafer & Yezierski (2021)	Investigating How Assessment Design Guides High School Chemistry Teachers' Interpretation of Student Responses to a Planned, Formative Assessment.
18	Hagos & Andargie (2022)	Technology-Integrated Formative Assessment: Effects on Students' Conceptual Knowledge and Motivation in Chemical Equilibrium.
19	Jammeh et al., (2023)	The Interactive Classroom: Integration of SMART Notebook Software in Chemistry Education.
20	Zemel et al., (2021)	Preservice Teachers' Enactment of Formative Assessment Using Rubrics in the Inquiry-Based Chemistry Laboratory.

Table 4
Source Hong et al (2018)

Research Design	Assessment Criteria / Quality Appraisal
Qualitative	• Is the qualitative approach appropriate to answer the research question? (QA1) • Are the qualitative data collection methods adequate to address the research question? (QA2) • Are the findings adequately derived from the data? (QA3) • Is the interpretation of results sufficiently substantiated by data? (QA4) • Is there coherence between qualitative data sources, collection, analysis, and interpretation? (QA5)
Quantitative	• Is randomization appropriately performed? (QA1) • Are the groups comparable at baseline? (QA2) • Are there complete outcome data? (QA3) • Are outcome assessors blinded to the intervention provided? (QA4) • Did the participants adhere to the assigned intervention? (QA5)
Quantitative non-randomized	• Are the participants representative of the target population? (QA1) • Are measurements appropriate regarding both the outcome and intervention (or exposure)? (QA2) • Are there complete outcome data? (QA3) • Are the confounders accounted for in the design and analysis? (QA4) • During the study period, is the intervention administered (or exposure occurred) as intended? (QA5)
Quantitative descriptive	• Is the sampling strategy relevant to address the research question? (QA1) • Is the sample representative of the target population? (QA2) • Are the measurements appropriate? (QA3) • Is the risk of nonresponse bias low? (QA4) • Is the statistical analysis appropriate to answer the research question? (QA5)

Mixed method	• Is there an adequate rationale for using a mixed methods design to address the research question? (QA1) • Are the different components of the study effectively integrated to answer the research question? (QA2) • Are the outputs of the integration of qualitative and quantitative components adequately interpreted? (QA3) • Are divergences and inconsistencies between quantitative and qualitative results adequately addressed? (QA4) • Do the different components of the study adhere to the quality criteria of each tradition of the methods involved? (QA5)

Table 5
Result of quality appraisal

Research	Research Design	QA1	QA2	QA3	QA4	QA5	Number of Criteria Fulfilled	Article Inclusion
Easa & Blonder (2022)	MX	√	√	√	√	√	5/5	√
Boesdorfer & Daugherty (2020)	MX	x	√	√	x	√	3/5	√
Babinčáková et al., (2020)	QL	√	√	√	x	√	4/5	√
Abell & Sevian (2020)	QL	√	√	√	x	√	4/5	√
Ochsen et al.,(2023)	QL	x	√	√	√	√	4/5	√
Bernard et al., (2019)	QL	x	√	√	√	√	4/5	√
Bernal-Ballen & Ladino-Ospina (2019)	QL	√	√	√	√	√	5/5	√
Ryan & Stieff (2019)	MX	√	√	x	√	x	3/5	√
Orduña Picón et al., (2020)	QL	√	√	√	√	√	5/5	√
Nsabayezu et al., (2022)	MX	√	√	√	x	x	3/5	√
Yik et al., (2021)	QN	√	√	x	√	√	4/5	√
Abell & Sevian (2021)	QL	√	√	√	√	√	5/5	√
Schafer & Yezierski, (2020)	QL	√	√	√	√	√	5/5	√

Vogelzang et al., (2021)	MX	√	√	x	x	√	3/5	√
Babinčáková et al., (2023)	QL	√	√	√	√	√	5/5	√
Murray et al., (2020)	QL	√	√	√	√	√	5/5	√
Schafer & Yezierski (2021)	QL	√	√	√	√	√	5/5	√
Hagos & Andargie (2022)	QL	√	√	x	x	√	3/5	√
Jammeh et al.,(2023)	QN	x	√	x	√	√	3/5	√
Zemel et al.,(2021)	MX	x	√	x	√	√	3/5	√

Results and Discussion

Research on the topic of formative assessment strategies has been conducted globally. Based on Figure 2, the United States of America leads in the contribution to research on formative assessment practices, producing 11 publications (Boesdorfer & Daugherty, 2020; Ochsen et al., 2023; Ryan & Stieff, 2019; Orduña Picón et al., 2020; Schafer &Yezierski, 2021; Vogelzang et al., 2021; Abell & Sevian, 2020; Abell & Sevian, 2021; Yik et al., 2021; Schafer &Yezierski, 2020; Murray et al., 2020). Two studies originated from Israel Easa & Blonder (2022); Zemel et al (2021) and two from Slovakia Babinčáková et al (2020); Babinčáková et al (2023) while single studies were conducted in various countries, including an African country Nsabayezu et al (2022), Poland Bernard et al (2019), Gambia Jammeh et al (2023), and Colombia (Bernal-Ballen, & Ladino-Ospina, 2019). An additional study was conducted in Ethiopia (Hagos & Andargie, 2022). (See Figure 2)

The highest percentage of articles from the United States with 55%, while Israel and Slovakia recorded 10 %. The rest country such as Poland, Africa, India, Colombia and Ethiopia contributed one article to this study with 5%. United States country as a developed country conducted a wide range of formative assessments, especially in chemistry educational settings.

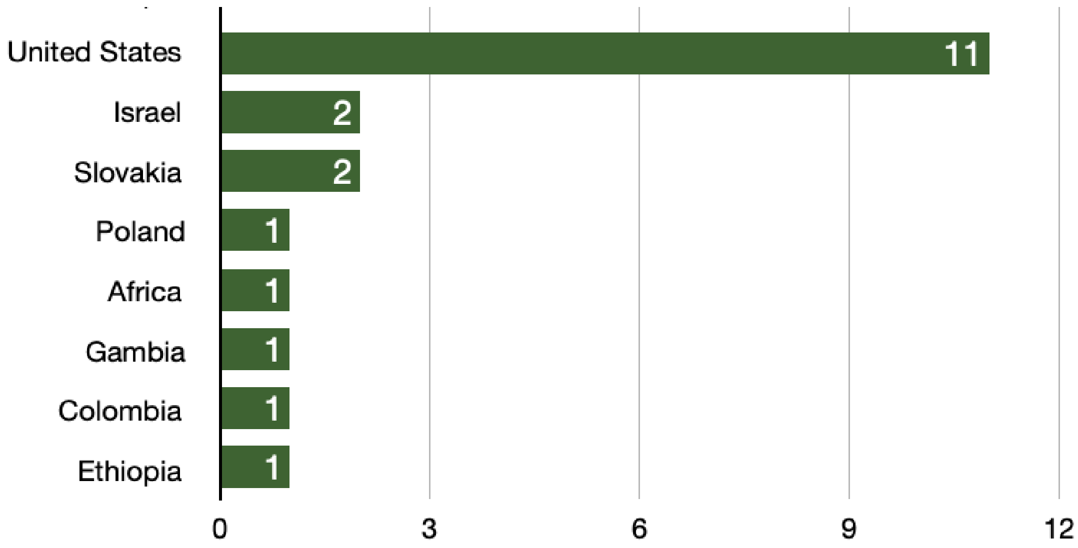

Figure 2: Countries where the studies were conducted

It was recorded that studies focused on 12 qualitative, while the other six studies focused on mixed-method analyses. Two studies employed the quantitative approach (See Figure. 3)

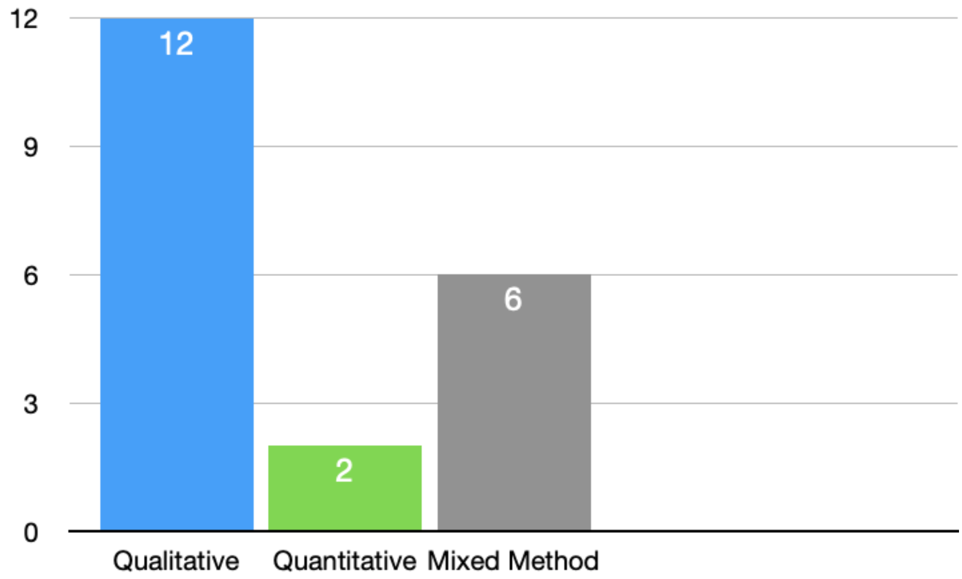

Figure 3: Research Design Of Selected Studies

Qualitative research design shows the highest percentage of 60% in this study compared to the mixed method with 30%. The lowest research design is through the quantitative method with 10%. The qualitative approach in most research was likely to gain an in-depth and more contextual understanding of formative assessment practice.

The data indicates the following trends in article publications by year: three articles were produced in 2019. The data increased by six articles in 2020 and five in 2021, then three articles were selected in 2022 also three articles by 2023. (See Figure 4)

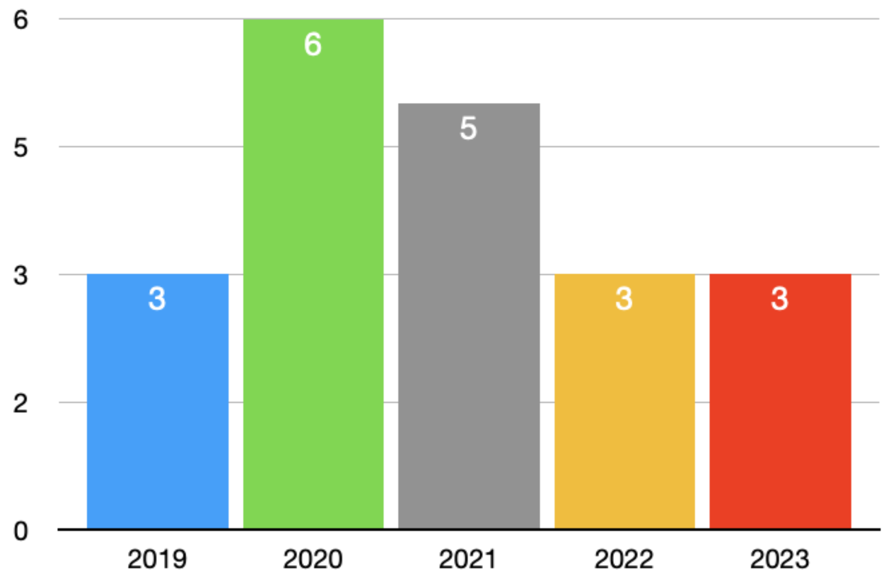

Figure 4: Publication years of selected studies

Based on the years of publication, 2020 shows the highest percentage, with 30%, and the year 2021 with 25%. The year 2019, 2022 and 2023 has the lowest percentage of publications with 15%. The pandemic COVID-19 in 2020 and 2021 shifted the remote learning, especially in educational settings with highlighting more research needed to enhance learning even during the pandemic.

Research Question 1: What strategies are used by teachers in formative assessments in chemistry classes among secondary schools?

From the 20 articles, this SLR research reveals the primary research questions that address the strategies in formative assessment. These strategies in formative assessment can be divided into four themes; Teaching and Learning approach, Assessment Tools, Professional Development and Technology Integration.

a) Teaching and learning approach

This systematic review discusses the variety of teaching and learning approaches within formative assessment activities being used in chemistry classrooms. Implementing formative assessment using Scrum methodology is effective when groups with this teaching strategy outperform compared to a control group (Vogelzang et al., 2021). Bernal-Ballén and Ladino-Ospina (2019) highlighted the uses of performance assessments and portfolios as alternative assessments during teaching to reveal the misconception of students concerning the topic of equilibrium using the instruments method. These findings correlate with Easa and Blonder's (2022) use of Customized Pedagogical Kits (CPK) in teaching strategy. The diagnostic tasks in this kit are designed to detect students' misconceptions at the early stage. Focusing on mastery learning in teaching with the use of digital badges in redox reaction as a strategy revealed that students' engagement increased and demonstrated a significant improvement in the summative assessment results for the redox topics (Boesdorfer & Daugherty, 2020).

Alternatively, inquiry-based teaching incorporates formative assessment methods (Bernard et al., 2019; Babinčáková et al., 2020; Babinčáková et al., 2023). Students actively participated in their designed experiments within self-created groups. However, they brought dilemmas to the teachers Bernard et al (2019) compared to Formative Assessment Classroom Techniques (FACTs) which show teachers' positive attitudes. FACTs are a flexible approach that enables teachers to adjust their instruction based on student's needs. The findings of Murray et al (2020) about assessing students' work with descriptive and inferential. Using these two approaches, teachers can detect four patterns of student thinking in chemistry concepts. In contrast, Bernal-Ballen and Ladino-Ospina (2019) used eight assessment instruments in chemical equilibrium to improve students' understanding. Picón et al (2020) implemented the formative assessment with a conceptual profile, to interpret students' thinking about substances in chemistry classrooms during conducting of formative assessment.

b) Assessment Tools

Tools in formative assessment bring significant effects and are well articulated in most research. Rubrics are the most noticeable formative assessment tools used in classrooms (Zemel et al., 2021; Bernard et al., 2019; Ochsen et al., 2023; Nsabayezu et al., 2022). Rubrics in formative assessment offer a standard assessment guideline (Zemel et al., 2021). This is because it describes detailed criteria in assessment (Bernard et al., 2019). Utilizing rubrics in digital will equip teachers to assess students' work clearly while improving students' achievement as per teacher expectations (Nsabayezu et al., 2022). The acceleration of technologies produced more developed assessment machines, as discussed by Yik et al., (2021), which draw on rubrics in the machines to detect students' answers in Lewis Acid-based models. Digital badges are also discussed in this study as tools, and the combination with teaching strategy will support academic achievement (Boesdorfer & Daugherty, 2020).

Even in this digital era, traditional methods such as drawing still demonstrate values, which affects assessing students in specific chemical concepts. Drawing is seen to activate students' grasp and enhance valuable learning (Ryan & Stieff, 2019). This traditional tool is reported as an effective tool in formative assessment to offer students mental modes which provide richer information to identify the possibility of misconception and capability to hold conceptual features. Furthermore, a set of pedagogical kits called CPK is used as tools in formative assessment as highlighted by Easa and Blonder (2022). Customised Pedagogical Kits (CPK) provide various pedagogical approaches once they have identified misconceptions. The treatment includes differentiated learning activities such as games, inquiry activities, puzzles, simulations, and models.

c) Technology

Technological advancements provide instant feedback specifically for students' engagement in learning (Van der Kleij et al., 2015). Multiple studies have emphasized integrating tools with technology as the key focal point of technology use (Nsabayezu et al., 2022; Yik et al., 2021; Boesdorfer & Daugherty, 2020; Jammeh et al., 2023). Technological tools and software like SMART Notebook software and Kahoot! Quizs also play a crucial role in student engagement and outcomes. This strategy brings into the classroom, accelerates feedback and maintains transparency during assessment (Zemel et al.,2021; Hagos & Andargie, 2022). In contrast with this study, a write-to-learn called LBB intervention strategy was used in this formative assessment with a technology-based approach (Ochsen et al., 2023). In addition, Kahoot!, an online game-based learning platform was expected to have a positive impact on students' situational interests. However, findings in Ochsen et al (2023), each student engaged in the same situational interest as another method. These observations argue not only for best practices for delivering feedback but also for a more comprehensive approach to giving feedback.

d) Professional development

Professional development activities of teaching and learning approaches are reviewed in this area. Teachers' beliefs and practices on formative assessment are influenced by professional development (Widiastuti et al., 2022). This is because it would elevate formative assessment practices for chemistry teachers (Abell & Sevian, 2020). Professional development can entail collaboration among teachers focusing on conversational trends and potential areas for progression (Schafer & Yezierski, 2020). Moreover, strategies focusing on domain-general aspects in a year-long professional development program for chemistry teachers lead to adopting a chemical thinking perspective in this course (Abell & Sevian, 2021). This dynamic instructional process entangles constant feedback and reflective practices in students' performance and highlights the active role of educators in creating design strategies and interpreting formative assessments accurately (Schafer & Yezierski, 2021).

Considering this viewpoint above, a blend of various pedagogical approaches, with assessment tools and the use of technology, are indispensable in embedding formative assessment effectively. Roles of professional development programs are a critical facet to augment this integration. The formative assessment strategies in this study are evident with a multitude of approaches of 16 combinations, encompassing diverse tools and methods, instructional techniques, integration of technology, and professional development, as summarized in Table 6.

Table 6

Research	**Themes**			
	TLA	**A**	**T**	**PD**
Writer (Year)				
Easa & Blonder (2022)	X	X		
Boesdorfer & Daugherty (2020)	X	X	X	
Babinčáková et al., (2020)	X			
Abell & Sevian (2020)				X
Ochsen et al., (2023)		X	X	
Bernard et al.,(2019)	X	X		
Bernal-Ballen, & Ladino-Ospina (2019)	X			
Ryan & Stieff (2019)		X		
Orduña Picón et al., (2020)	X			
Nsabayezu et al., (2022)		X	X	
Yik et al., (2021)		X	X	
Abell & Sevian (2021)				X

Schafer & Yezierski (2020)				X
Vogelzang et al., (2021)	X			
Babinčáková et al., (2023)	X			
Murray et al.,(2020)	X			
Schafer & Yezierski (2021)				X
Hagos & Andargie (2022)			X	
Jammeh et al., (2023)			X	
Zemel et al.,(2021)		X	X	

Note: TLA (Teaching Learning & Approach) ; AT (Assessment Tools); PD (Professional Development); T (Technology)

Research Question 2: How does the implementation of varied formative assessment strategies enhance student's learning in chemistry classrooms?

a) Conceptual Understanding

Formative assessment strategies have proven important in enhancing students' understanding of chemistry concepts. This can be explained by Black et al.,(2004) where the conceptual learning in students can be enhanced if the teachers adjust their teaching based on students' feedback, align with formative assessment objectives, and support increased students' conceptual understanding. Rubrics created by the Ministry of Education for the preservice teacher have improved conceptual understanding (Zemel et al., 2021). Similarly, Nsabayezu et al (2022) stated that rubrics in formative assessments improve students' understanding and increase retention of organic chemistry concepts. Implementing tools like digital badges improved students' conceptual understanding by comparing the number of badges to represent students' conceptual understanding (Boesdorfer & Daugherty, 2020). In contrast, Jammeh et al (2023) found that using SMART notebook software that contains interactive worksheets with a fast response system significantly improved conceptual and academic achievements. Assessment tools with technology foster an in-depth understanding of the Lewis acid-base model. It required students to explain written responses, reinforce the concept, and promote the development of critical thinking and reasoning skills (Yik et al., 2021). Meanwhile, the teacher's interpretation of student's responses impacts the understanding of the concept (Schafer & Yezierski, 2021).

In addition, self-assessment and student engagement increased in learning by mapping concepts (Babinčáková et al., 2020). Compared to CPK kits, it will improve students' understanding through pedagogical treatments by addressing misconceptions and difficulties in chemistry learning (Easa & Blonder 2022). These research results align with post-test scores for conceptual knowledge and motivation (Hagoss & Andargie, 2022). Teachers' reflection in professional development produces best practices for assessment that focus on assessing conceptual understanding (Schafer & Yezierski, 2020). It is correlated with noticing students' work which can promote the meaningful construction of new understandings (Murray et al., 2020). After the discussion above, it can be concluded that most teachers evaluated students' work to assess conceptual understanding, but in some cases, teachers also provide corrective feedback to address knowledge gaps.

b) Critical Thinking

The 21st-century global challenges require the students to complete themselves with a range of skills to compete globally. Critical thinking is one of the skills needed to face globalization (Nurhijrah et al., 2020). Critical thinking is utilizing knowledge and being able to address arising problems, use discernment in decisions, and execute investigations based on knowledge and data (Kriswantoro et al., 2021). The combination of diverse approaches in formative assessment is pivotal in fostering critical thinking in chemistry students. Conceptual profile through heterogeneous thinking underscores concepts and promotes critical thinking from different perspectives (Orduña Picón et al., 2020). The digitalized rubric as an assessment tool can foster critical thinking if is designed properly and elucidates expectations in students' work (Nsabayezu et al., 2022). Abell and Sevian (2020) mentioned that real-world scenario drives students in critical thinking and problem-solving skills. They emphasized chemical thinking is part of critical thinking and cultivates a more nuanced understanding of chemical and principal structure. Formative assessment techniques with technology are employed to enhance critical thinking (Hagos & Andargie, 2022; Jammeh et al., 2023). In addition, assessment tools such as open-ended assessments and scrum methodology promote critical thinking (Yik et al., 2021; Murray et al., 2020; Vogelzang et al., 2021).

c) Problem-Solving

Bernal-Ballen and Ladino-Ospina (2019) suggested that the pivotal part of problem-solving skills is that students must be able to make self-assessments and identify their weaknesses. An interactive classroom enhances this skill through the participation of students in active learning. It shows that technology integration supports their problem-solving capabilities through practice (Jammeh et al., 2023). Besides that, particularly in laboratory circumstances, this supports problem-solving during hands-on activities as highlighted by Zemel et al.,(2021). The best practices in the formative assessment conducted properly through teacher collaboration would support problem-solving aptitude (Abell & Sevian, 2020). Giving useful feedback is seen as beneficial in implementing FACTs in the classroom, which supports these skills (Babinčáková et al., 2020; Babinčáková et al., 2023). Furthermore, the teachers also suggested that a crucial part of problem-solving skills is that students must be able to make a self-assessment and identify their weaknesses.

d) Motivation

This study reported that students' motivation depends on their intrinsic motivation to seek challenges and learn new concepts. In contrast, extrinsic motivation depends on external rewards given by the teacher and school (Hagos & Andargie, 2022). Mastery learning with digital badges was found to increase student motivation (Boesdorfer & Daugherty, 2020). It is aligned with Easa and Blonder (2022), whose pedagogical treatment with game-playing elements made the learning process and assessment more entertaining. Jammeh et al., (2023) highlight the effective implementation of formative assessment not only in conceptual understanding and critical thinking but also in actively engaging students' participation. They used SMART notebook with software integration to motivate and promote independent learning. Formative assessment also promotes self-assessments as mentioned by (Babinčáková et al., 2023). The combination of student's autonomy and meaningful tasks also contributes to students' motivation, like the uses of Scrum methodology (Vogelzang et al., 2021).

e) Scientific Skills

In education, scientific skills are essential, especially in a general science context. The blending of technology in formative assessment is the most crucial part discussed in this research. It effectively enhances students' learning in chemistry, especially in the development of scientific skills (Hagos & Andargie, 2022; Yik et al., 2021; Nsabayezu et al., 2022; Jammeh et al., 2023; Ryan & Stieff, 2019; Ochsen et al.2023). It can be explained even though the 20 assessment strategies implemented are different, it will bring significant effects on the development of scientific skills. This is elaborated by Yik et al., (2021) and Nsabayezu et al., (2022) who state that using written and machine tools increases students' engagement and grasp of scientific principles while digitalized rubrics lead to acquiring student knowledge. It is proven that diverse strategy in formative assessment improves scientific skills. Compared to these studies, conventional methods such as laboratory skills that align with inquiry-based learning at each laboratory level also suggest the necessity of scientific skills (Zemel et al., 2021).

f) Communication Skills

Formative assessment acts as a major instrument to enhance students' learning by improving student's communication skills. Rubrics also facilitate communication with an enhancement of social integration in the classroom, which promotes communication skills between teachers and students. Students will assess their communication skills through meaningful comments from teachers (Bernard et al., 2019). Communication using Gmail provides a platform for students to get instruction from teachers in giving instant feedback (Nsabayezu et al., 2022).

In this discussion, formative assessment is seen as enhancing students' understanding through conceptual understanding, problem-solving, critical thinking, motivation, scientific skills, and communication skills. In the article on formative assessment in chemistry, formative assessment strategies are seen to have an impact on not only to one skill but various skills to improve student learning in the subject of chemistry. The research concludes that various assessment strategies show different outcomes as outlined in Table 7.

Table 7

Research	**Themes**					
	CU	**CT**	**PS**	**M**	**SC**	**CS**
Writer (Year)						
Easa & Blonder (2022)	X			X		
Boesdorfer & Daugherty (2020)	X			X		
Babinčáková et al. (2020)	X		X			
Abell & Sevian (2020)		X	X			
Ochsen et al. (2023)					X	
Bernard et al. (2019)						X
Bernal-Ballen & Ladino-Ospina (2019)			X			
Ryan & Stieff (2019)					X	
Orduña Picón et al., (2020)		X				
Nsabayezu et al (2022)	X	X			X	X
Yik et al. (2021)	X	X			X	
Abell & Sevian (2021)						
Schafer & Yezierski (2020)	X					
Vogelzang et al (2021)		X		X		
Babinčáková et al (2023)			X	X		
Murray et al.,(2020)	X	X				
Schafer & Yezierski (2021)	X					
Hagos & Andargie (2022)	X	X		X	X	
Jammeh et al., (2023)	X	X	X	X	X	
Zemel et al.,(2021)	X		X		X	

Note: CU (Conceptual Understanding); CT (Critical Thinking); PS (Problem-Solving); M (Motivation); SC (Scientific Skill); CS (Communication Skills).

Research Question 3; What are the challenges faced by teachers in implementing formative assessment strategies in their chemistry classrooms?

This review accentuates the primary challenges that teachers face, as incorporating formative assessment into chemistry education can be more challenging. Despite its benefits, many teachers still prefer summative exams, which limits their usage (Bernal-Ballen & Ladino-Ospina, 2019; Bernard et al., 2019). This resistance highlights the need for teachers to get more experience in designing inquiry-based learning and developing practical approaches to assessment. Identifying students' thinking is also a complex task, which makes it more challenging to integrate formative assessment (Orduña Picón et al., 2020). Additionally, time constraints can make it difficult to provide students with extra time to complete assessments and prepare materials such as digital badges and FACTs (Boesdorfer & Daugherty, 2020; Babinčáková et al., 2023).

Moreover, addressing issues and problems in formative assessment strategies is crucial to ensure the practical implementation of formative assessment in chemistry education and assessment plans (Babinčáková et al., 2023; Hagos & Andargie,2022). Teachers also need support to use data to inform the instruction, make modifications to teaching strategies and improve the learning area (Schafer & Yezierski, 2020). The teachers' consistency in grading also brings an issue in providing students with accurate feedback for improvement and in shifting the assessment which is not only correct or incorrect. This can hinder the implementation to achieve targeted outcomes in formative assessment (Zemel et al., 2021). Teachers' beliefs and focus on mastery of learning only in teaching and learning, will prevent them from an approach adjustment, especially in the observation of student's work (Abell & Sevian, 2021). Even though the effectiveness of the scrum methodology has been discussed, teachers have different proficiencies in employing tools and methods like Scrum methodology (Vogelzang et al., 2021). This is quite different from Babinčáková's (2020) result of using FACTs, even if these strategies are effective, teachers do not use the evidence for the next lesson and something to be re-evaluated.

Sometimes, the advancement of technologies creates some hurdles, as discussed in (Yik et al., 2021). This problem is about the accuracy of machine tools in interpreting terms of written students' responses. Most students stressed the time spent assessing internet connection and functionality of digital devices as technical problems while using digitalized rubrics (Nsabayezu et al., 2022). During the formative assessment, the primary purpose of formative assessment is to collect evidence so that teachers can adjust the instruction. However, this implementation has become more complex when interrelated with classroom practice. Moreover, in the classroom context, a large class size consumes time to provide detailed feedback to each student (Hagos & Andargie, 2022).

Teachers require strategies to adjust different instructions because students' learning styles are different and require considerable effort from teachers to plan the strategies in formative assessment (Easa & Blonder, 2022). This becomes even more challenging when students show little interest in formative assessment (Ochsen et al., 2023). Besides the employment of assessment results being crucial for instructional decisions, the study reported a more prominent concern about teachers needing more expertise to interpret students' responses and adjust their teaching method (Schafer & Yezierski, 2020).

Conclusion

Generally, the SLR presented in this article shows the blending of assessment tools, teaching and learning approaches, technology digitals and professional development. All the strategies that have been discussed can have different degrees of effectiveness, especially in students' learning in chemistry. Formative assessment in chemistry is essential, therefore it is vital to adjust teaching methods and modify instruction to identify the strengths and weaknesses of students' areas. The effectiveness of formative assessment will enhance students' understanding through the development of conceptual understanding, critical thinking, problem-solving, scientific skills, and communication skills. Hence, teachers not only validate the lesson on formative assessment practice but also improve the practice to fulfil student's skills (Lyon et al., 2019). Based on this study, successful strategies in formative assessment rely on many factors, such as classroom management, students' interests, teachers' competencies, and school policies.

To achieve high-quality assessment, the main obstacles, like time constraints, teacher competencies, and student engagement, must be mitigated using digital assessment tools data, ongoing professional development, and a variety of assessment tools that focus on learning goals for students. The education field is constantly evolving with technological advancement, new theories, new paradigms, changes in policy and shifts in culture. Thus the strategies in the classroom also need to undergo continuous evaluation. This research particularly in formative assessment in chemistry will contribute to innovation in strategies and the development of tools and techniques, therefore it will help teachers to manipulate a variety of approaches due to classroom and students' needs and allow students to enhance their understanding and develop many skills as global development.

As a recommendation based on the findings, digital technology and managing teachers' workload are approaches that need attention in this finding from the teacher's perspective, as well as considering the student's perception during the assessment process in the chemistry subject. Teaching methods also need more innovative assessment tools that can be integrated with technology and these strategies would help students to self-assess, therefore facilitating teachers' tasks. In addition, research should also point out the challenges and advantages of using these strategies. Continuous research, as suggested will give insightful perspectives on formative assessment which potentially improve student outcomes and ultimately contribute to advancements in these fields that rely on chemical knowledge and student skills.

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