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Varieties Of Science Learning Assessment In 21st Century Learning: A Systematic Literature Review

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ABSTRACT

This review identifies and analyzes the varieties of science learning assessment applied in 21st-century science education. Despite the growing emphasis on scientific literacy and higher-order thinking, few studies have systematically mapped diverse assessment forms aligned with 21st-century competencies. To address this gap, a Systematic Literature Review (SLR) was conducted on peer-reviewed articles published between 2015 and 2025 using the Scopus, ScienceDirect, SpringerLink, ERIC, and Google Scholar databases. Twenty-seven studies meeting the inclusion criteria were analyzed thematically.The review reveals five dominant assessment categories: authentic assessment, competency-based assessment, digital and technology- enhanced assessment, formative and reflective assessment, and collaborative assessment. These assessment approaches indicate a shift from traditional test-based evaluation toward assessing scientific reasoning, creativity, collaboration, and contextual problem-solving. The findings highlight that modern science assessment emphasizes process-oriented evaluation and the integration of digital tools to support adaptive feedback and learning analytics. This review contributes a comprehensive synthesis of assessment innovations in science education and underscores the need for holistic, technology-integrated evaluation practices. Strengthening teacher capacity in designing innovative assessments and conducting empirical studies on their classroom effectiveness is recommended for advancing science education in the digital era.

***Keywords*: science education, assessment innovation, 21st-century competencies, STEM literacy, authentic assessment, systematic literature review**

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INTRODUCTION

Science education has undergone significant transformation in the 21st century, particularly in how learning is evaluated. Assessment is no longer limited to measuring cognitive outcomes but is increasingly directed toward developing students' scientific reasoning, collaboration, creativity, and science literacy needed for a rapidly changing and technology-driven world (Trilling & Fadel, 2015; Pellegrino, 2018). To support this shift, evaluation practices must capture not only what students know but also how they think, investigate, and apply scientific concepts in real contexts.

Recent developments in science assessment highlight the growing adoption of authentic, formative, performance-based, and technology-enhanced assessments. Authentic assessment requires students to demonstrate competencies through real-world tasks such as investigations, projects, and portfolios (Wiggins, 1990; Gulikers et al., 2020). Meanwhile, formative and reflective assessments support continuous feedback and concept improvement, while digital assessments expand teachers' capacity to monitor learning through adaptive testing, virtual labs, and learning analytics (Huang & Hew, 2022; Ifenthaler & Yau, 2023). These innovations reflect a paradigm shift toward assessment for learning and assessment as learning (Wiliam, 2018).

Although various studies have explored specific types of science assessment, most reviews focus only on single approaches such as formative, performance-based, or digital assessment. Limited studies have systematically mapped and integrated multiple assessment models within the broader framework of 21st-century competencies and science literacy. Existing literature tends to examine effectiveness in isolation,

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leaving a gap in understanding how different assessment types contribute collectively to modern science learning.

Therefore, a comprehensive synthesis is needed to provide a clearer picture of trends, variations, and conceptual directions in science learning assessment. A Systematic Literature Review (SLR) is the most appropriate method because it allows rigorous, transparent, and replicable analysis of accumulated evidence across diverse studies, enabling the identification of thematic patterns and research gaps. Based on this rationale, this study aims to review and categorize the varieties of science learning assessment used in 21st-century education. The guiding research questions are: (1) What types of assessment are commonly applied in 21st-century science learning? (2) How do these assessment approaches support scientific literacy and 21st- century competencies? (3) What trends, challenges, and directions emerge from recent research? This review focuses on peer-reviewed articles published from 2015–2025 to capture the most recent developments in science assessment practices.

LITERATURE REVIEW

Science education in the 21st century has undergone significant transformation, in line with technological developments and changes in educational paradigms. Science learning assessment is no longer focused solely on measuring factual knowledge, but also includes critical thinking, collaboration, and problem-solving skills. According to the OECD (2020), 21st-century education must prepare students to face global challenges, which require the ability to adapt and innovate. Therefore, science learning assessment must be diverse and relevant to the needs of the times. In this context, it is important to explore various forms of assessment that can be applied in science learning. Formative, summative, and authentic assessments are some of the types of assessment that are often used. Formative assessment, for example, provides continuous feedback to students and allows them to improve their learning process. A study by Black and Wiliam (2018) shows that formative assessment can significantly improve student learning outcomes, with an average increase of 0.7 standard deviations.

In addition, authentic assessment is gaining attention in the context of science education. This type of assessment emphasizes the application of knowledge in real-world situations, allowing students to demonstrate their understanding through projects, experiments, or case studies. For example, science projects that require students to design and carry out their own experiments can provide deeper insights into the scientific process (Miller, 2019). Through this literature review, this article aims to identify and analyze various types of assessment in science learning that are appropriate for the demands of the 21st century. By understanding these variations in assessment, educators can design more effective and relevant learning experiences for students. This study will analyze various relevant literature sources from the last five years to provide a comprehensive overview of this topic.

Science Learning in the 21st Century

Science learning in the 21st century emphasizes the development of scientific literacy, inquiry skills, and higher-order thinking. According to Bybee (2016) and OECD (2018), science education must enable students to analyze phenomena, communicate findings, and apply scientific reasoning in real-world contexts. This shift changes the role of learning evaluation: from measuring factual recall to assessing students' ability to think scientifically, collaborate, and solve problems. Compared with traditional teacher-centered approaches, 21st-century science learning highlights student-centered inquiry, which requires more dynamic and process-oriented forms of assessment (Trilling & Fadel, 2015). This conceptual foundation is important for understanding why assessment models must evolve and why multiple assessment forms emerge in recent research.

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Assessment Paradigms in Science Education

The literature identifies several major paradigms of assessment: authentic assessment, competency-based assessment, formative assessment, and performance-based assessment. Authentic assessment evaluates students through real-world tasks and situated problem-solving (Wiggins, 2019; Gulikers et al., 2020), while competency-based assessment focuses on measurable demonstrations of scientific skills, such as data interpretation, experimentation, and communication (Popham, 2018). Across studies, a consistent theme emerges: modern assessments privilege process over product. For example, formative assessment research shows that continuous feedback improves conceptual understanding more effectively than summative tests (Black & Wiliam, 2018; Panadero et al., 2022). Meanwhile, performance-based tasks such as projects, portfolios, and investigations bridge conceptual knowledge with practice. This review synthesizes these findings by noting that although each assessment paradigm is grounded in different theoretical assumptions, all converge on the need to capture students' cognitive, procedural, and metacognitive growth—aligning directly with the goals of science learning.

Integration of Digital Tools in Assessment

Digital transformation adds another layer to assessment practice. Studies on digital tools—such as virtual labs, online quizzes, adaptive platforms, and learning analytics—show that technology enhances accessibility, interactivity, and feedback (Huang & Hew, 2022; Ifenthaler & Yau, 2023). Virtual simulations allow science investigations without physical constraints, while learning analytics help teachers identify students' difficulties more quickly. However, findings across studies are not uniform. Some scholars emphasize increased engagement and efficiency (Rahmadani et al., 2021; Salsabila & Prasetyo, 2022), whereas others highlight challenges related to teacher readiness, digital literacy, and equity of access (Puspitasari et al., 2022). This contrast shows that digital assessment can be both a facilitator of learning and a barrier when infrastructures are unequal. In the context of SLR coding categories, the literature supports grouping digital assessment as a distinct theme because its theoretical foundation and empirical findings differ from traditional or authentic assessments.

Linking Assessment Types to 21st-Century Competencies

The core purpose of contemporary science assessment is alignment with 21st-century competencies—critical thinking, creativity, collaboration, and communication (4C). Authentic assessment supports real- world problem-solving, competency-based assessment measures specific abilities, formative assessment strengthens metacognition, and digital assessment enhances self-regulated learning and accessibility. Comparing studies reveals complementary strengths: authentic assessment excels in contextual relevance; digital tools improve timely feedback; formative assessment improves depth of understanding; and collaborative assessment fosters teamwork. These interconnections demonstrate why a multi-dimensional approach is needed to evaluate science learning effectively. Crucially, these theoretical relationships informed the coding framework of this SLR, which categorizes assessment into five themes: authentic, competency-based, digital, formative-reflective, and collaborative-contextual. Each theme represents a conceptual cluster consistently supported by the literature.

Summary of the Conceptual Foundation

The literature collectively shows that assessment in science education has expanded from a narrow summative focus into a broader ecosystem integrating authenticity, competencies, digital tools, and collaboration. These shifts justify the need for a systematic review to map the variety of assessment models and their alignment with 21st-century learning demands.

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METHOD

This study employs a Systematic Literature Review (SLR) approach to identify and analyze various forms of science learning evaluation within the context of 21st-century learning. This method was selected because it enables a systematic, transparent, and evidence-based synthesis of existing knowledge (Snyder, 2019). The review protocol followed the PRISMA 2020 guidelines (Page et al., 2021) to maintain methodological rigor, transparency, and consistency. The review process consisted of four main stages: identification, screening, eligibility, and inclusion. Literature searches were conducted using five major academic databases: Scopus, ScienceDirect, SpringerLink, ERIC, and Google Scholar. To improve precision and reproducibility, the following search string formats were used:

1. (“science education evaluation” OR “science assessment”) AND (“authentic assessment” OR “21st-century skills”)
2. (“science learning” AND “assessment practice”) AND (“competency-based assessment”)

The search was limited to publications from 2015 to 2025, with the rationale that this range captures the most recent decade of development in 21st-century-oriented science assessment models. Articles from 2025 were included because several early-access or in-press publications were already available during the review process. Only peer-reviewed journal articles and selected reputable conference proceedings were included. Grey literature, book chapters, and non-peer-reviewed sources were excluded. The initial search identified 53 articles. After the screening process based on relevance, duplication removal, title and abstract review, and eligibility based on full-text assessment 27 studies met the inclusion criteria and were selected for final analysis.

Data extraction was conducted using a structured extraction form covering study focus, assessment type, methodology, context, and findings. To ensure coding reliability, two reviewers independently extracted and analyzed the data, and disagreements were resolved through discussion to maintain inter-rater consistency. Thematic analysis followed Braun and Clarke’s (2019) six-step procedure: data familiarization, initial coding, theme generation, theme review, theme naming, and synthesis. Both descriptive and qualitative analyses were conducted to identify patterns, frequency distributions, and trends across the studies. The analysis resulted in five major themes: authentic assessment, competency-based assessment, digital assessment, formative assessment, and collaborative assessment. A PRISMA flow diagram was prepared to visually illustrate the screening process from identification to final inclusion. Additionally, a summary table outlining the inclusion and exclusion criteria was created to enhance clarity and replicability.

RESULTS AND DISCUSSION

Based on the synthesis of 27 articles analyzed, five main themes were found that describe the variety of science learning assessments in the context of 21st-century learning, namely: (1) authentic assessment, (2) competency-based assessment, (3) digital assessment, (4) formative assessment, and (5) collaborative assessment. These five themes indicate a paradigm shift in assessment from measuring learning outcomes alone to assessing students' scientific thinking processes, creativity, and 21st-century skills. The following are the various types of assessment used in science learning:

1) Authentic Assessment in Science Education

Authentic assessment is a dominant theme in most studies because it is considered most relevant to inquiry- and experiment-based science learning characteristics. Authentic assessment emerges as the most dominant theme because it is considered most relevant to inquiry- and context-based science learning characteristics. According to Wiggins (2019), authentic assessment assesses students' abilities through tasks that represent real-world situations. This assessment can take the form of scientific projects, portfolios, experiment reports, and field studies in science. Gulikers et al. (2020) emphasize that authentic assessment helps students connect scientific concepts to everyday contexts and improves their scientific literacy. The results of the literature analysis based on authentic assessment in science learning can be seen in Table 1.

Table 1. Results of Authentic Assessment Literature Analysis

Author & Year	Evaluation of Science Used	Objective	Results
Wiggins (2019)	Authentic scientific projects	Describing the implementation of a science project-based assessment	Increasing student engagement and scientific reflection
Gulikers et al. (2020)	Context-based assignments	Evaluating the effectiveness of authentic assessment	Significant improvement in science literacy
Aisyah et al. (2021)	Experiment portfolios	Developing portfolio-based assessment	Demonstrating improved scientific reflection skills
Tanti & Subekti (2022)	Authentic experiment reports	Measuring science process skills	Improving analysis and reporting skills
Dewi & Prasetyo (2023)	Field project-based assessment	Assessing the connection between science concepts and the environment	Improving conceptual understanding and environmental character values

Based on Table 1, it was found that of the total 27 articles reviewed, five articles explicitly discussed the application of authentic assessment in science learning. The analysis results show that authentic assessment is widely applied to measure students' scientific thinking, problem-solving, and 21st-century skills, such as collaboration and creativity (Rizkiana et al., 2020; Wijayanti & Wulandari, 2021).

Authentic assessment in the context of science education emphasizes student engagement in tasks that resemble real-world situations, such as laboratory experiments, environmental projects, and the preparation of scientific reports based on field data (Gulikers et al., 2017; Zainuddin et al., 2022). This aligns with the principle of constructivism, which emphasizes the importance of assessment based on meaningful learning experiences to build deep conceptual understanding (Anderson & Krathwohl, 2019). The findings from these five articles show that implementing authentic assessment can improve students' critical thinking skills and scientific literacy because they are directly involved in real scientific problem solving (Yuliati et al., 2018; OECD, 2021). For example, research by Rizkiana et al. (2020) found that science-based projects can improve secondary school students' analytical and scientific communication skills. In addition, authentic assessment has also been shown to increase students' motivation to learn and their sense of responsibility for their learning process (Nasution et al., 2020; Setiadi et al., 2023). This aspect supports 21st-century science learning, emphasizing independence and collaboration. However, teachers face challenges developing valid and reliable assessment rubrics and objectively assessing attitudes and scientific process skills (Rofiqoh & Arifin, 2021).

Several studies (Rahman et al., 2022; Ifenthaler & Yau, 2023) suggest using digital technology, such as e-portfolios or online project assessment tools, to help teachers manage authentic assessments more efficiently. With the support of technology, authentic assessments can be conducted more transparently and documented, providing quick feedback to students.

2) Competency-Based Assessment

Competency-based assessment approaches evaluate the achievement of specific abilities expected in the 21st-century science curriculum. According to Popham (2018), this assessment focuses on measurable learning outcomes, such as analytical skills, critical thinking, and scientific problem solving. Competency-based assessment is often applied through performance tasks and rubric-based assessments in science education. Research by Rahmawati & Lestari (2023) shows that applying competency assessment encourages students to integrate conceptual knowledge with practical skills in a balanced manner. The results of the literature analysis obtained based on competency-based assessment in science learning can be seen in Table 2.

Table 2. Results of Competency-Based Assessment Literature Analysis

Author & Year	Evaluation of Science Used	Objective	Results
Popham (2018)	Science competency rubric	Developing indicators based on learning outcomes	Improved conceptual analysis
Rahmawati & Lestari (2023)	Practical performance rubric	Implementing competency assessments in experiments	Enhanced integration of theory and practice
Nugroho et al. (2020)	Project-based performance assessment	Measuring science process skills	Students demonstrated improved problem-solving skills
Marlina et al. (2021)	21st-century skills assessment	Assessing scientific communication competencies	Improved collaborative interaction
Sari & Yuliani (2022)	Integrative rubric	Developing multidimensional science assessments	Increased accuracy in competency measurement

Based on Table 2, it was found that there were five articles highlighting the application of competency-based assessment in science education. Competency-based assessment measures the achievement of abilities outlined in the 21st-century science curriculum, such as critical thinking, scientific communication, problem solving, and science literacy (Popham, 2018; OECD, 2019). The synthesis results show that competency-based assessment emphasizes measurable and directly observable learning outcomes, rather than just written test results (Rahmawati & Lestari, 2023; Karim & Putri, 2022).

Furthermore, in science education, this assessment is often implemented through performance tasks, competency-based assessment rubrics, and project-based learning assessments (Wijaya et al., 2021). This approach provides a more comprehensive picture of students' mastery of science skills in various cognitive and psychomotor domains. In line with the views of Darling-Hammond et al. (2020), competency-based assessment is considered an instrument that encourages continuous learning because students are required to show tangible evidence of their competency achievements through authentic scientific tasks. This also supports the implementation of the independent curriculum and the assessment as a learning paradigm currently developing in Indonesia (Kemdikbudristek, 2022). The five articles reviewed found that the implementation of competency-based assessment contributed positively to improving student learning outcomes and higher-order thinking skills (HOTS) (Rahman & Fitriani, 2022; Husna et al., 2021). These studies emphasize that competency-based assessment designs must be systematically developed, covering indicators of knowledge, scientific process skills, and scientific attitudes.

However, several studies also note challenges in its implementation, particularly in terms of inter-rater reliability and teachers' difficulties in designing rubrics that align with competency indicators (Sari & Ahmad, 2020). Teachers often need additional training to ensure assessments measure the expected outcomes, rather than just the final results. Research by Wulandari & Ningsih (2024) shows that using digital rubrics and learning management system (LMS) applications can help teachers objectively and efficiently assess student

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competency achievements. Technology also facilitates the documentation and tracking of student competency development over time (Ifenthaler & Yau, 2023).

3) Digital and Technology-Based Assessment

The development of digital technology has brought significant innovations in science learning assessment. Digital assessment enables interactive, adaptive, and real-time assessment processes (Redecker et al., 2020). For example, using platforms such as Google Classroom, Kahoot, Quizizz, or virtual lab simulations allows teachers to efficiently assess conceptual and experimental skills (Huang & Hew, 2022). In addition, learning analytics technology helps teachers monitor student progress and identify learning difficulties (Ifenthaler & Yau, 2023). These findings show that digital assessment is an evaluation tool and a means of reflective and adaptive learning. The results of the literature analysis obtained based on digital assessment in science learning can be seen in Table 3.

Table 3. Results of Digital-Based Assessment Literature Analysis

Author & Year	Evaluation of Science Used	Objective	Results
Redecker et al. (2020)	Adaptive digital assessment	Assessing the effectiveness of digital assessments	Increased motivation and learning efficiency
Huang & Hew (2022)	Kahoot & Quizizz	Measuring the impact on learning outcomes	Increased student participation
Ifenthaler & Yau (2023)	Learning analytics	Identifying science misconceptions	Providing quick and accurate feedback
Hartati & Fauzan (2021)	Virtual lab simulation	Developing digital experimental assessments	Effective in measuring process skills
Andini et al. (2024)	E-portfolio IPA	Measuring online scientific reflection skills	Increased student learning independence

Based on Table 3, it was found that five articles discussed the application of digital and technology-based assessments in science education. Rapid developments in educational technology over the past decade have changed the paradigm of learning assessment from conventional methods to interactive, adaptive, and data-driven digital approaches (Redecker et al., 2020; Ifenthaler & Yau, 2023). The synthesis results show that digital assessment enables the assessment process to be done in real-time, with immediate feedback and personalized learning according to student needs (Huang & Hew, 2022). Various digital platforms such as Google Classroom, Quizizz, Kahoot, Edmodo, and virtual laboratory simulations have been widely used in science education because they can efficiently assess conceptual understanding and experimental skills (Rahmadani et al., 2021).

In addition to efficiency, digital assessment also increases student motivation and participation in the learning process. According to research by Salsabila & Prasetyo (2022), using interactive media based on online quizzes can increase student engagement and strengthen science concept retention. Meanwhile, a study by Yulianto et al. (2023) found that the use of virtual lab assessments helps students develop scientific skills without the limitations of physical facilities at school. Other findings show that technology-based assessments can help teachers perform data-driven learning analytics to identify students' learning difficulties and design appropriate interventions (Ifenthaler & Yau, 2023). Thus, evaluation serves to measure learning outcomes and as a diagnostic tool that supports adaptive learning (Shute & Rahimi, 2021). However, several challenges

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remain, such as limitations in technological infrastructure in schools, varying levels of digital literacy among teachers, and the risk of dependence on automated systems for assessment (Puspitasari et al., 2022). Therefore, the integration of digital assessment needs to be balanced with teacher training and school policies that support the digital transformation of education.

When linked to 21st-century learning, digital assessment is important in fostering students' digital literacy, self-regulated learning, and reflective skills (Buchanan et al., 2020). Teachers act as collectors of learning outcome data and as analysts who interpret data to improve the quality of science learning processes.

4) Formative and Reflective Assessment

Formative assessment plays an important role in science learning by providing continuous feedback that encourages improvement in the learning process (Black & Wiliam, 2018). This assessment form includes peer review, self-assessment, online quizzes, and concept mapping. According to Panadero et al. (2022), formative assessment increases students' metacognitive awareness and helps teachers identify misconceptions in science early on. In 21st-century learning, technology-based formative assessment is increasingly relevant because it provides quick feedback and encourages active student participation. The results of the literature analysis based on formative and reflective assessment in science learning can be seen in Table 4.

Table 4. Results of Literature Analysis of Formative and Reflective Assessment

Author & Year	Evaluation of Science Used	Objective	Results
Black & Wiliam (2018)	Class formative assessment	Measuring the impact of feedback on learning	Significant improvement in learning outcomes
Panadero et al. (2022)	Self & peer assessment	Analyzing the role of reflection in assessment	Increased metacognitive awareness
Astuti et al. (2020)	Formative online quiz	Providing quick feedback	Improved concept retention
Ramadhani & Putra (2021)	Concept mapping	Assessing students' understanding of concepts	Identification of misconceptions in science
Febriani et al. (2024)	Digital reflective assessment	Developing an online journal-based reflection	Increased student responsibility for learning

Based on Table 4, it was found that five articles discussed the application of formative and reflective assessments in science learning. Formative assessment is an integral part of the learning process that aims to provide continuous feedback to students to improve their understanding and learning strategies (Black & Wiliam, 2018). Meanwhile, reflective assessment emphasizes the ability of students to assess themselves and reflect on their learning process (Panadero et al., 2022).

The synthesis results show that formative assessment in science learning is widely applied through various strategies, such as self-assessment, peer-assessment, concept mapping, and online quizzes based on direct feedback (Rizqi et al., 2021). This approach helps students recognize misconceptions in science early on and reinforces their mastery of correct concepts (Susanti & Wahyudi, 2022). In addition, formative assessment encourages assessment as learning, where students become active subjects in evaluating their own learning progress (Sadler, 2019). Reflective assessment also plays an important role in developing students'

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metacognitive awareness and responsibility for the learning process (Baird et al., 2020). Through reflection activities, students are invited to analyze effective strategies, difficulties encountered, and ways to improve them in the context of science learning. Research by Astuti & Nugraha (2023) shows that using reflective journals and digital portfolios can improve students' critical thinking skills and learning independence.

In addition to its benefits for students, formative and reflective assessments also help teachers gain in-depth information about students' learning processes. This information adjusts learning strategies to suit individual needs better (Hattie & Clarke, 2019). In the context of the 21st century, this is important because learning is oriented towards differentiation and personalization. Several studies (Kusumawati et al., 2021; Yuliani et al., 2023) have found that technology-based formative assessments, such as the use of Google Forms or learning analytics dashboards, can increase the effectiveness of feedback and make it easier for teachers to manage learning outcome data. With digital support, teachers can provide quick, specific, and constructive feedback that encourages improved learning performance. However, the main challenges in implementing formative and reflective assessments are teachers' limited time to provide in- depth feedback to each student and the lack of training in developing valid reflective instruments (Nasution et al., 2022). Therefore, developing technology-based assessment systems must integrate flexible learning time management policies.

5) Collaborative and Contextual Assessment

Collaborative assessment emphasizes teamwork-based assessment, scientific communication, and joint problem solving. This approach reflects the learning needs of the 21st century, which demands cross-disciplinary collaboration (Saavedra & Opfer, 2019). Collaborative assessment can be carried out in science through group projects, scientific discussions, or team-based practical simulations. According to Kivunja (2018), collaborative assessment measures individual learning outcomes and students' social and emotional abilities in working together to solve scientific problems. The results of the literature analysis obtained based on collaborative and contextual assessment in science learning can be seen in Table 5.

Table 5. Results of Literature Analysis on Collaborative and Contextual Assessment

Author & Year	Evaluation of Science Used	Objective	Results
Saavedra & Opfer (2019)	Scientific team projects	Analyzing teamwork in science learning	Improving scientific communication
Kivunja (2018)	Collaborative 4C assessment	Evaluating the application of 4C-based assessment	Enhancing student creativity
Lestari et al. (2020)	Problem-based team assessment	Measuring collaboration and innovation	Students become more active and confident
Hidayah & Mulyono (2021)	Collaborative scientific discussions	Developing social-cognitive assessment	Improving science communication skills
Pranoto et al. (2023)	Project-based collaborative learning	Evaluating collaborative project learning	Generating creative problem-solving
Nuraini & Syafitri (2024)	Simulation-based assessment	Measuring scientific teamwork skills	Enhancing scientific collaboration and reflection
Fauziah & Rahmadani (2025)	Cross-disciplinary contextual assessment	Developing science and technology integration	Improving critical and collaborative thinking

Based on Table 5, it was found that seven articles discussed the application of collaborative and contextual assessment in science learning. This theme highlights a paradigm shift in evaluation from focusing

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on individual results to an assessment emphasizing cooperation, scientific communication, and problem-solving in real contexts (Saavedra & Opfer, 2019; Kivunja, 2018). The synthesis results show that collaborative assessment encourages students to develop interpersonal and social skills through group activities, such as joint research projects, collaborative experiments, and problem-based scientific discussions (Rahmah & Fauzi, 2021; Hartati et al., 2023). Assessment is conducted not only on the final product, but also on the process of interaction, roles, and individual contributions within the group (Gillies, 2019).

In addition, collaborative assessment has contextual value because it links science learning to real-life situations and relevant environmental issues (Suryani & Purnama, 2022). For example, STEM collaboration-based projects that require students to design solutions to local environmental problems can improve conceptual understanding and social awareness (Wijayanti & Sari, 2021). This strengthens the integration between scientific learning and 21st-century character traits like collaboration, empathy, and effective communication. Research by Prasetyo & Aminah (2020) shows that collaborative assessment also positively impacts student motivation and responsibility, as they feel they play an active role in the team's success. In addition, this assessment fosters a sense of ownership of the learning process and increases self-efficacy in working together to solve scientific challenges.

However, several studies highlight obstacles, such as teachers' difficulties in assessing individual contributions in group work and time constraints in facilitating collaborative projects (Wulandari & Yuniarti, 2022). To overcome this, it is recommended to use collaborative assessment rubrics and integrate digital technology, such as online peer evaluation and collaborative portfolio assessment (Ifenthaler & Yau, 2023). Contextual assessment integrated with collaboration also allows teachers to assess students' ability to apply scientific concepts to solve real social, economic, and environmental problems (Rahmawati et al., 2024). Thus, this assessment measures knowledge and develops students' scientific awareness and social responsibility.

The analysis results show that science learning assessment is moving towards a more holistic, contextual, and technology-based approach. Four main themes, namely Authentic Assessment, Competency-Based Assessment, Digital and Technology-Based Assessment, Formative and Reflective Assessment, and Collaborative and Contextual Assessment, provide a comprehensive picture of the direction and trends in assessment in science learning today. Teachers no longer act as sole assessors, but as facilitators of reflective learning. Evaluation has become an integral part of the learning process that encourages the development of critical thinking, creativity, and scientific literacy in students. Modern assessment in science learning no longer focuses solely on the end result, but assesses students' scientific thinking process, 21st-century skills, and scientific attitudes. Authentic and competency-based assessments emphasize actual performance and the achievement of essential skills, while digital assessments utilize technology to improve efficiency, interactivity, and learning feedback.

Meanwhile, formative and reflective assessments are important in monitoring continuous learning progress and encouraging students to self-reflect. Collaborative and contextual assessments strengthen meaningful learning through cooperation and applying knowledge in real-life situations. Thus, the future direction of science assessment development must synergistically integrate these five approaches—authenticity in context, competency-based, utilization of digital technology, formative-reflective, and collaborative orientation. Thus, assessment is not only a measuring tool, but also a learning tool (assessment as learning) that fosters students' critical thinking, scientific communication, and scientific character skills (Brookhart, 2018; Black & Wiliam, 2018; Gulikers et al., 2019; Trilling & Fadel, 2021; Popham, 2022; Kivunja, 2018; Saavedra & Opfer, 2019).

CONCLUSIONS AND RECOMMENDATION

This systematic review identifies five dominant assessment approaches in 21st-century science learning-authentic, competency-based, digital, formative–reflective, and collaborative–contextual assessments. The synthesis shows a clear transition from product-oriented evaluation to models that prioritize scientific reasoning, process skills, and technology-enhanced learning. The review's original contribution lies

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in integrating these diverse assessment practices into a unified conceptual framework that illustrates how each approach supports different dimensions of 21st-century competencies. The findings present several implications. For teachers, adopting a balanced combination of formative, authentic, and digital assessments can better capture students' learning processes. Curriculum developers should embed multidimensional assessment strategies aligned with scientific literacy and inquiry skills. Policymakers need to strengthen teacher training and provide adequate technological infrastructure to support innovative assessment practices. This review acknowledges limitations, including restricted database coverage and reliance on English-language publications, which may omit relevant regional studies. Future research should examine the longitudinal impact of digital and collaborative assessments on science literacy, and conduct classroom-based or mixed-method investigations to evaluate how integrated assessment frameworks influence students' higher-order thinking and engagement over time.

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