Authentic Assessment in Chemistry Education at Senior High Schools and Higher Education: A Systematic Literature Review (2015–2025)

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Abstract. This study aims to systematically examine the types, implementation, roles of educators, and challenges in the application of authentic assessment in chemistry education at the senior high school and higher education levels. The research team searched the literature using the Publish or Perish software, accessed through the Google Scholar database, for the period from 2015 to 2025. From an initial 200 articles identified, screening based on inclusion and exclusion criteria yielded 25 relevant articles for further analysis. Data were analysed qualitatively using a thematic approach based on four main research questions. The findings reveal that educators have implemented authentic assessment in various forms, including performance assessment, projects, portfolios, inquiry-based experiments, e-portfolios, as well as self- and peer-assessment. These models emphasise a holistic integration of cognitive, affective, and psychomotor domains. Educators implement authentic assessments in diverse learning contexts, both face-to-face and online, and often integrate them with real-world, problem-based activities. Teachers and lecturers play roles as instrument designers, learning facilitators, and providers of formative feedback. However, the implementation of authentic assessment still faces several challenges, such as time constraints, limited facilities, digital readiness, and a lack of educator training. This review recommends policy support and the strengthening of teacher and lecturer capacity to ensure the effective implementation of authentic assessment in chemistry education.

Keywords: authentic assessment; chemistry education; senior high school; higher education.

INTRODUCTION

The transformation of education in the 21st century demands fundamental changes in both learning and student assessment approaches. One increasingly recognised approach is authentic assessment, which not only evaluates cognitive learning outcomes but also emphasises the application of knowledge in real-life situations. Within the framework of the Merdeka Curriculum at the school level and the reinforcement of competency-based learning in higher education, authentic assessment has become an integral part of developing essential skills such as critical thinking, problem-solving, collaboration, and communication [1]. Thus, this assessment approach bridges classroom learning with the real world, equipping students with relevant competencies to face global challenges [2].

However, in the practice of chemistry education at both senior high schools and universities, assessment approaches are still frequently dominated by conventional methods focused on rote memorisation and theoretical mastery. Studies have shown that such assessments fail to adequately reflect students' ability to apply chemical concepts in contextual and functional ways [3]. Moreover, traditional assessments often overlook other important aspects of science education, such as science process skills and scientific attitudes [4, 5].

There is now a growing need to integrate assessments that comprehensively evaluate conceptual understanding, science process skills, and scientific attitudes. Research has demonstrated that authentic assessment provides a more holistic picture of students' competencies across these domains [6, 7]. Practices such as project-based laboratory work, inquiry-based assessments, and problem-solving tasks provide students with opportunities to apply their knowledge, engage in scientific thinking, and demonstrate scientific attitudes, including curiosity and perseverance [8, 9].

Despite the proven benefits of authentic assessment, its implementation continues to face significant challenges. Authors [10] highlight key obstacles, including limited resources, inadequate educator training, and time constraints; this is supported by authors [11], who emphasise the need for developing assessment instruments aligned with learning models, and authors [12], who recommend technical training for educators to improve assessment quality.

The COVID-19 pandemic has exacerbated these challenges by limiting access to laboratory facilities and shifting learning to online environments [13]. On the other hand, technological advancements have created new opportunities, such as the use of interactive applications and educational games to enhance assessment quality [14, 15]. Additionally, given the socio-cultural diversity of students in Indonesia, inclusive and culturally relevant assessment approaches are crucial for improving motivation and participation [16].
Over the past decade, studies on authentic assessment have expanded at both the secondary and tertiary education levels. However, these findings remain scattered and have yet to be systematically reviewed, particularly in the context of chemistry education. Therefore, a systematic review is needed to comprehensively map practices, challenges, and development opportunities in authentic assessment. Such a review is essential for providing an evidence-based foundation to strengthen education policy and more relevant, effective, and contextual teaching practices.

This study focuses on systematically compiling and analysing various studies that discuss authentic assessment in chemistry education at the senior high school and university levels from 2015 to 2025. The main objective of this review is to identify the forms and models of authentic assessment, evaluate its implementation in the learning process, analyse the roles of educators in its design, and explore the challenges in implementing authentic assessment in chemistry classrooms at both levels.

To achieve this objective, the study was designed to address the following research questions:

1) What are the forms and models of authentic assessment used in chemistry education at the senior high school and university levels, based on studies published between 2015 and 2025?

2) How is authentic assessment implemented in the chemistry learning process at both senior high schools and universities according to existing research findings?

3) What are the roles of educators (teachers and lecturers) in designing and implementing authentic assessment in chemistry education at these levels?

4) What challenges and barriers have been reported in the implementation of authentic assessment in chemistry classes at the secondary and tertiary levels?

METHOD

This study employed a Systematic Literature Review (SLR) approach to collect, identify, and systematically analyse scholarly articles discussing authentic assessment in chemistry education at the senior high school and higher education levels, published between 2015 and 2025.

Inclusion Criteria. The research team selected the articles included in this systematic review based on the following criteria:

1) Discuss authentic assessment in the context of chemistry education at the senior high school and/or higher education level.

2) Are scholarly articles published in nationally or internationally indexed reputable journals and available in full-text?

3) They were published between 2015 and 2025 to ensure relevance with current developments in authentic assessment.

4) Employ an empirical research design (quantitative, qualitative, mixed-methods, developmental, or classroom action research) or evaluative-descriptive studies and present data related to the implementation of authentic assessment.

5) They are written in either Indonesian or English.

6) Provide explicit information regarding the forms/models of assessment, implementation process, educator roles, and/or challenges in implementing authentic assessment.

Exclusion Criteria. Articles were excluded from the systematic review if they:

1) Do not specifically discuss authentic assessment in chemistry education or only mention it in general without a detailed discussion.

2) They are not within the context of senior high school or higher education (e.g., elementary education or non-formal education).

3) Do not present empirical data or implementation analysis of authentic assessment (e.g., editorials, opinion pieces, or theoretical narratives without supporting data).

4) They are not available in full-text form.

5) They are written in languages other than Indonesian or English.

6) Are duplicates of the same publication or earlier versions of already selected articles?

Article Search Strategy. The research team conducted the article search using Publish or Perish software, which is connected to Google Scholar. They used keywords such as "authentic assessment," "chemistry education," "senior high school," and "higher education," combining them flexibly to retrieve relevant articles.

Analysis Procedure. From the initial search results, articles were screened through several stages, including a review of the title, abstract, and full text to ensure alignment with the inclusion criteria. A total of 25 selected articles were then analysed using a synthesis table based on the four research questions (RQs). The research team employed a qualitative approach to examine the content of the articles, focusing on the types of assessments used, implementation strategies, the roles of educators, and the challenges reported.

Data Validity. The research team conducted data collection and classification carefully and iteratively to ensure the accuracy of the analysis. Validation was conducted through peer discussions among researchers and cross-checking between articles to ensure consistency of the findings.

RESULTS AND DISCUSSION

The following result table presents a synthesised summary of 25 selected articles, organised according to four key research questions: (RQ1) the forms and models of authentic assessment; (RQ2) the implementation strategies; (RQ3) the roles of educators; and (RQ4) the challenges encountered. Each entry includes the authors, the type of assessment utilised, the implementation methods in chemistry instruction, the educators' contributions, reported barriers, and the educational level (high school or higher education). This tabular synthesis serves as the foundation for the thematic discussion presented in the subsequent subsections.

Table 1 – Summary of Research Findings on the Implementation of Authentic Assessment in Chemistry Education (2015–2025)

No	Authors	RQ1	RQ2	RQ3	RQ4	Level
1	[17]	Cognitive (tests), affective (attitude), self-efficacy, and peer assessment. Forms: portfolios, task documentation.	Implemented through Contextual Teaching and Learning (CTL) in two action cycles using both test and non-test instruments (questionnaires, observations).	Lecturers designed instruments (expert validated), facilitated project tasks, observations, and provided reflective feedback.	-	HE
2	[18]	Integrated authentic assessment with metacognitive strategies. Forms: written reflection, self-assessment, and rubrics.	Applied through project-based and reflective tasks in science instruction. Conducted throughout the learning process.	Teachers designed rubrics, incorporated metacognitive strategies, and guided student reflection and self-assessment.	Limited time, added workload, and low student readiness for self-reflection.	HE

No	Authors	RQ1	RQ2	RQ3	RQ4	Level
3	[19]	Process-based assessment during semi-structured inquiry experiments.	Students conducted inquiry-based labs, engaged in problem-solving activities, and delivered open-class presentations. Weekly quizzes based on theory and experimental data.	Lecturers created inquiry tasks, provided limited facilitation, and guided reflections.	Student adaptation issues, long experiment duration, and uneven group participation.	HE
4	[20]	Electronic portfolios, mastery-based gated tests, online quizzes, clicker assessments, adaptive homework, and team-based projects.	Applied in general chemistry with semi-self-paced flipped learning: pre-class (videos/readings), in-class (POGIL, discussions), post-class (online tasks).	Designed learning and assessment flow, provided direct and LMS-based feedback, facilitated discussion and progress-based adaptation.	High instructor workload, initial student difficulty with self-paced learning, and disparities in tech access.	HE
5	[21]	Peer assessment via a rubric on lab performance in basic chemistry skills.	Applied in lab sessions via peer observation of psychomotor skills.	Lecturers designed rubrics, facilitated observations, and verified peer assessments.	Dominance of paper-based tests, limited psychomotor/affective assessment, focus on group over individual, and added instructor workload.	HE
6	[22]	Digital-based authentic assessment to evaluate observation, inference, and prediction skills; implemented as mini-research projects.	Project-based assessment using digital media; student teachers performed observation, inference, and prediction from mini-experiments.	Lecturers served as assessors and facilitators, designed rubrics, and provided feedback on student projects.	Implicit challenges related to instrument validation and high faculty involvement.	HE
7	[23]	Project-based assessment includes technical project reports, self-reflection, a skill matrix, and real-world performance evaluation.	Students engaged in real industry projects via a "chemistry clinic"; assessment embedded in real-world project execution, followed by professional reporting and reflection.	Lecturers supervised projects, designed skill rubrics, provided formative feedback, and facilitated reflection.	Limited student access due to project capacity, variable industry quality, and limited institutional resources.	HE
8	[24]	Simulation-based formative assessment within real-world contexts (e.g., drinking water testing, bioremediation); focused on data analysis and problem solving.	Implemented through ChemVLab+, an online platform integrating real-life scenarios, virtual labs, and direct feedback, improved high school student learning outcomes.	The administrators provided teachers with a student progress dashboard but did not fully train them in developing authentic assessments.	Integration into formal curricula, classroom management in digital settings, and support for diverse learners.	SHS
9	[25]	Performance assessment using virtual labs,	Applied in PhET-based virtual chemistry labs; focused on direct	Teachers developed assessment tools based on student	Teachers' limited understanding of virtual labs, time-consuming	SHS

No	Authors	RQ1	RQ2	RQ3	RQ4	Level
		portfolios, scientific activity rubrics, and observational instruments.	evaluation of students' scientific performance in simulations.	needs and expert validation; facilitated virtual experiments and assessment processes.	scoring, and complex rubrics can divert their attention away from attitudes and scientific skills.	
10	[26]	Problem-based learning assessments, including case studies, oral presentations, and group reports, emphasised problem-solving, scientific argumentation, and reasoning.	Applied to chemistry students through real-world contexts (industry, pharmacy, forensics, environment) using scenario-based tasks.	Tutors provided assessment briefings, facilitated discussions, and gave feedback on problem-solving strategies and group dynamics.	Students struggled with complex criteria, were unfamiliar with reflection and justification, and lacked understanding of the PBL assessment format.	HE
11	[27]	Observation of process skills, inquiry skill rubrics, product and process evaluation, and integrated cognitive, affective, and psychomotor assessment.	Implemented through inquiry-based modules including experimentation, hypothesis development, observation, and result presentation with integrated authentic assessment.	The teacher acted as facilitator, assessor during instruction, and developer of modules and assessment rubrics.	Teacher challenges in inquiry implementation due to limited skills, lab resources, learning modules, and perceptions of authentic assessment as complex and time-consuming.	SHS
12	[28]	Observation, self-assessment, peer assessment, journals, practical tests, projects, and portfolios.	Applied through integrated assessment of attitude (via observation/journals), knowledge (written/oral tests, tasks), and skills (practical work, projects, portfolios) aligned with the scientific approach (5M).	Teachers developed indicators, selected assessment tools (e.g., observation sheets, rubrics), set criteria, and designed activities to foster attitudes, knowledge, and skills.	Lack of teacher understanding, administrative burden, limited time, and overload of multiple simultaneous assessment tools.	SHS
13	[29]	Three-dimensional learning assessment (3D-LAP), evaluating conceptual explanation and modelling of chemical phenomena.	Used in classrooms supportive of 3D assessment; 14–57% of exam scores measured connections between core ideas and real phenomena.	Teachers selected and implemented assessment models emphasising conceptual reasoning over factual recall.	Many classrooms still emphasise fragmented skills and factual recall, lacking structural support for authentic assessment.	HE
14	[30]	Performance assessment via achievement tests, formative questions, research-based and diagnostic tasks; facilitated through assessment-based learning manuals.	Implemented using formative assessment manuals in challenging chemistry topics (e.g., equilibrium, redox, electrochemistry).	The training team trained teachers in research- and assessment-based instruction, and the teachers conducted ongoing formative assessments.	Limited facilities in public schools and disparities in achievement by gender and school type.	SHS

No	Authors	RQ1	RQ2	RQ3	RQ4	Level
15	[31]	Reflective tasks using STEM-based Systems Thinking Enrichment Modules, including real-world photo-taking and open-ended analysis.	Online chemistry modules at the introductory level require students to link chemistry concepts with sustainability issues.	Lecturers developed the modules, provided stimuli, guided reflections, and evaluated systems thinking skills.	Student difficulty with cross-scale thinking, lack of motivation to connect chemistry to real life, and limited access to stimulus materials.	HE
16	[32]	Class-based authentic assessment, including cognitive (tests, reports, worksheets), affective, and psychomotor domains. Forms: portfolio, project, performance, and written tests.	Integrated into inquiry-based chemistry learning through experiments and lab reports; improved student scores across domains.	Teachers designed lesson plans, worksheets, and rubrics, conducted direct observation, and facilitated group experiments and discussions.	Students struggled with formulating hypotheses, participating in discussions, using equipment, and ensuring accuracy in data collection during the early cycles.	SHS
17	[33]	Tech-based authentic assessment: portfolios, lab reports, real-world problem-solving tasks, rubrics for discussion, scientific skills, and argumentation.	Implemented via LMS in an introductory analytical chemistry course; students uploaded reports, engaged in chemistry-based discussions, and reflected on learning.	Lecturers developed rubrics, monitored online discussions, assessed scientific reports and arguments, and provided direct feedback via LMS.	Low lecturer literacy in authentic assessment, limited time, difficulty verifying online conceptual understanding, and the need for additional observers and scorer calibration.	HE
18	[34]	Context-based formative essay tests assessing higher-order thinking (analysis, synthesis, evaluation).	Applied in contextual and conventional learning for Grade 11 chemistry; measured learning outcomes with attention to students' prior ability.	Teachers created context-rich essay questions, facilitated discussions, connected content to real-life experiences, and adjusted instruction to accommodate prior knowledge.	Not explicitly stated, but implied challenges in aligning assessment, methods, and student readiness.	SHS
19	[35]	Task-based e-portfolio (print/digital), including planning, curation, reflection, and assessment elements.	Implemented via Moodle to assess habits of mind and concept mastery; involved reflection and continuous feedback.	Teachers set assessment goals, chose platforms, developed rubrics, guided student reflection, and evaluated systematically.	Teachers' lack of readiness for digital assessment design, rubric validity, scoring subjectivity, and limited sample artefacts.	SHS
20	[36]	Lab-based assessment through an environmental approach; evaluated performance, observation, and student reflection.	Applied to topics like electrolytes, thermochemistry, and reaction rates using eco-friendly materials; piloted at two schools via the Plomp model.	Teachers developed and applied lab guides, facilitated experiments, posed reflective questions, and assessed both process and outcomes.	Limited lab facilities, labs used as classrooms, a shortage of standard chemicals/equipment, and language barriers.	SHS

No	Authors	RQ1	RQ2	RQ3	RQ4	Level
21	[37]	Class and homework tasks, student journals, process observation sheets, daily written tests, lab reports, and portfolios.	Implemented in Grade 10 chemistry through two action research cycles. Students completed worksheets, journals, individual tasks, and lab reports. Assessment was continuous and performance-based.	Teachers designed learning tools and rubrics, monitored student progress, archived portfolios, and provided feedback and scoring.	Limited teacher understanding, time constraints, unprepared students, absences, and high administrative workload.	SHS
22	[38]	Peer and self-assessment using the Teamwork Skills Inventory (TSI), a multi-rater tool with 25 indicators of collaborative skills.	Applied in cooperative learning across subjects, including chemistry. Students assessed themselves and their peers after four weeks of group work.	Teachers introduced the TSI tool, monitored group dynamics, gave individual feedback via Teacher Analytics Profile, and guided student reflections.	Lack of prior tools for fair collaboration assessment, potential dishonesty in ratings, and difficulty evaluating group dynamics objectively without peer input.	SHS
23	[39]	Oral and written rubrics assessing scientific accuracy, clarity, scientific language use, teamwork, and creativity. Activities included presentations, interactive exhibitions, and written outputs (e.g., posters, leaflets).	Implemented over seven sessions with inquiry modules on gases and dispersions. Students explored environmental issues (global warming, acid rain) via experiments, CO_2 analysis, and public exhibitions.	Teachers facilitated inquiry stages, provided formative feedback, guided research questions and data interpretation, and assessed progress using rubrics.	The articles do not explicitly state the challenges, but they imply a need for careful time planning, differentiated tasks, and intensive teacher guidance.	SHS
24	[24]	Formative assessment through ChemVLab+ simulations in real contexts (e.g., drinking water, sports drinks, oil spills) with auto-feedback and student progress reports.	Applied to over 1,400 high school students in online contextual learning. Virtual labs enabled authentic scientific investigation and concept understanding via macroscopic, microscopic, and symbolic representations.	Teachers chose when to implement modules, set working modes (individual/pairs), and used student performance reports to adapt instruction.	Students struggled with connecting chemical representations, with effectiveness varying by the timing/mode of use. Technical issues occurred in some schools.	SHS
25	[40]	E-portfolio via Google Classroom, including lab reports, concept maps, posters, and critical reflection.	Used in online learning, assignments submitted via LMS, teachers gave digital feedback, and students revised accordingly.	Teachers designed tasks that targeted critical thinking, provided formative feedback, and monitored student progress.	Internet issues, teacher workload, and lack of digital readiness among educators.	SHS

RQ1: Forms and Models of Authentic Assessment in Chemistry Education at Senior High School and Higher Education Levels. Authentic assessment in chemistry education encompasses a diverse range of forms and models, implemented across both senior high school (SHS) and higher education (HE) contexts. Based on the synthesis of 25 articles published between 2015 and 2025, five

dominant trends in the forms/models of authentic assessment were identified, as illustrated in Figure 1.

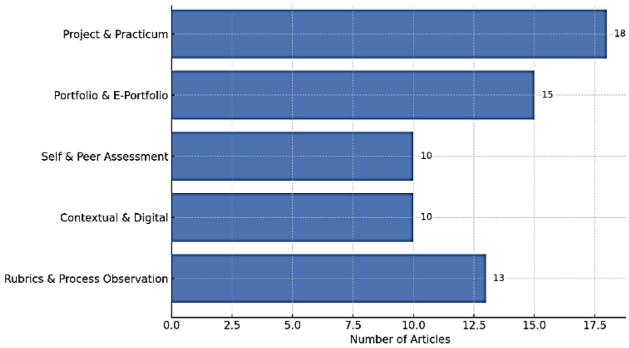

Figure 1 – Distribution of Authentic Assessment Models in Chemistry Education

1) Project- and Laboratory-Based Assessment. This type of assessment predominates across all educational levels. At the university level, examples include industry-based real-world projects [23], guided-inquiry laboratory experiments [24], and environmental analysis reports [31]. At the high school level, students were assessed through ecological projects, exhibitions, and eco-friendly laboratory practices to evaluate conceptual understanding and science process skills [36, 39].

2) Portfolio and E-Portfolio. Portfolio-based assessment appeared frequently in both physical and digital formats. In higher education, educators have used e-portfolios to assess students' habits of mind, conceptual mastery [35], and reflective abilities [33]. In senior high school (SHS), teachers employed portfolios to collect learning artefacts such as lab reports, journals, and concept maps [37, 40].

3) Peer and Self-Assessment. Peer and self-assessment were applied to evaluate collaborative skills and laboratory performance. For example, authors [21, 38] utilised tools such as the Teamwork Skills Inventory (TSI) and observational rubrics to assess group work and individual contributions in cooperative and lab-based settings.

4) Contextual and Technology-Based Assessment. Several studies integrated real-world contexts and digital technology into their assessment approaches. ChemVLab+, for instance, provided performance assessments through virtual lab simulations based on authentic problems [24, 25]. In higher education, similar methods have been implemented through Learning Management Systems (LMS) and digital rubrics [20, 22].

5) Rubrics, Observation Sheets, and Performance Instruments. Educators widely use scientific performance rubrics, observation tools, and performance checklists to evaluate student learning. These instruments assessed students' scientific skills, argumentation, observation, inference, and prediction abilities both directly and indirectly. Educators often integrated this approach with formative assessment, reflective practices, and continuous feedback [28].

In general, the findings suggest that the most commonly used forms and models of authentic assessment are project-based, laboratory-based, and portfolio-based assessments. These models support meaningful learning by evaluating both the process and outcomes of learning holistically. Furthermore, they help learners connect chemistry concepts with real-life contexts, enhance critical thinking skills, and foster active engagement in the learning process.

RQ2: Implementation of Authentic Assessment in Chemistry Education. The systematic review of 25 selected articles reveals that the implementation of authentic assessment in chemistry education at both the senior high school (SHS) and higher education (HE) levels has taken various forms that emphasise active student engagement throughout the learning process. This implementation goes beyond evaluating outcomes by focusing on scientific thinking, process skills, and the ability to apply concepts in real-world contexts.

To clarify the stages and actors involved in the implementation process, Figure 2 presents a swimlane diagram illustrating the flow of authentic assessment in chemistry learning.

The diagram organises responsibilities into three main components: teacher/lecturer, student, and digital platform/instrument. The assessment process consists of four primary stages: planning, implementation, formative feedback, and evaluation and reflection.

This figure highlights the active and continuous involvement of students, with teachers playing a dominant role in the initial planning and facilitation phases. Meanwhile, technology serves as a key enabler for collaboration, progress tracking, and digital portfolio management.

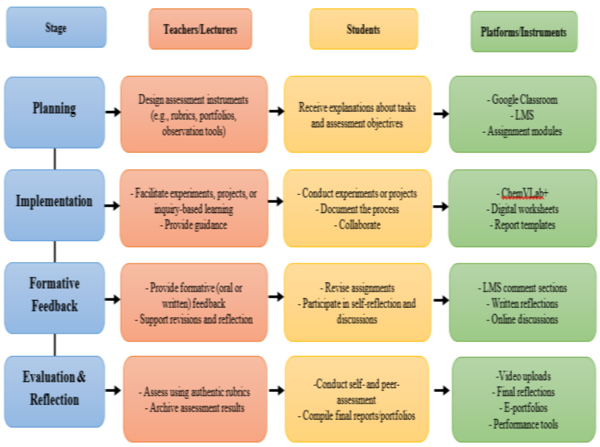

Figure 2 – Swimlane Diagram of Authentic Assessment Implementation

Based on the literature review, the concrete implementation of authentic assessment can be categorised into the following key practices:

1) Integration into Inquiry- and Project-Based Learning. Authentic assessment is commonly applied within inquiry-based learning [27, 32] and project-based learning environments [23, 39]. In these approaches, students engage in exploration, experimentation, and problem-solving activities that are relevant to daily life. Assessment occurs both during the learning process and at its conclusion.

2) Utilisation of Technology and Digital Platforms. With technological advancement, authentic assessment is increasingly implemented through digital media and online learning platforms such as Google Classroom, ChemVLab+, and Moodle LMS [24, 33, 40]. In these settings, students submit assignments such as lab reports, reflections, and projects and receive direct feedback from instructors. These platforms also allow structured tracking of student learning progress.

3) Emphasis on Process Over Product. Authentic assessment prioritises not only correct answers but also the evaluation of scientific reasoning, laboratory skills, and communication abilities [24, 31]. Instruments such as observation rubrics, reflective journals, self-assessments, and practical tests are employed to capture these dimensions.

4) Collaboration and Reflection-Based Assessment. Several studies incorporate peer and self-assessment to foster students' collaborative and reflective skills [21, 38]. These practices encourage learners to objectively evaluate their individual and group strengths and weaknesses, promoting shared responsibility in the learning process.

5) Real-World Context Application. Educators also implement authentic assessment in contexts that simulate real-life situations, such as tasks related to industry, environmental issues, or everyday scenarios [23, 30]. For example, instructors may require students to write technical reports based on real projects or analyse the environmental impact of CO_2 emissions.

6) Flexible Timing and Continuous Integration. In some studies, authentic assessment is implemented in a phased and repeated manner across a semester or more, indicating its integration as an ongoing part of the learning process [30, 37]; this reflects its role as more than a single assessment event, but rather as a holistic instructional strategy.

In conclusion, educators generally implement authentic assessment in chemistry education through active and contextual learning strategies. They embed it throughout the learning process in various formats, such as projects, experiments, portfolios, reflections, and digital collaboration. This approach enhances student engagement and brings chemistry closer to real life. However, successful implementation requires strong support in terms of planning, assessment instruments, and the assessment literacy of teachers and lecturers.

RQ3: The Role of Educators in Designing and Implementing Authentic Assessment. The systematic review of 25 articles reveals that educators, including both secondary school teachers and university lecturers, play a pivotal role in the successful implementation of authentic assessment in chemistry education. Their responsibilities extend far beyond the technical execution of assessments; they encompass the design, facilitation, monitoring, and reflection of the learning process.

1) Designers of Relevant and Diverse Assessment Instruments. Educators are responsible for developing various assessment tools, including performance rubrics, observation sheets, portfolios, self- and peer-assessment instruments, and performance-based tests [17, 21, 22]. In this role, teachers and lecturers not only construct the tools but also ensure their validity and reliability through expert review or field trials.

2) Facilitators of Learning and Assessment. Another key role is that of a facilitator, where edu-

cators guide students throughout the learning and assessment process; this includes providing clear instructions, supervising experiments or projects, and offering formative feedback [23, 32, 37]. At the higher education level, lecturers also lead reflective and scholarly discussions as integral parts of the assessment process.

3) Continuous Monitors and Evaluators. Educators are tasked with monitoring student progress continuously rather than only at the end of the instructional period. Some studies indicate that teachers utilise Learning Management Systems (LMS) to track students' assignments and activities [33, 40] while lecturers employ skill matrices or analytics dashboards for monitoring purposes [38].

Teachers and lecturers also play a crucial role in designing authentic and contextual learning scenarios, such as environmental projects, industry case studies, or real-world problem-solving tasks [31, 39]. These tasks are tailored to local contexts or global issues that are relevant to students' lives.

4) Participants in Professional Development. Several studies emphasise that educators cannot optimally carry out these roles without professional development in authentic assessment [12, 28]. Many educators still face significant challenges in assessment literacy, especially when developing valid instruments and providing effective formative feedback.

In conclusion, teachers and lecturers hold critical responsibilities across all stages of authentic assessment, from design and implementation to evaluation. They not only develop the assessment tools but also facilitate active learning processes, guide reflection and collaboration, and ensure that assessment outcomes genuinely reflect students' competencies. These roles require creativity, strong pedagogical skills, and ongoing support through targeted professional development.

RQ4: Challenges and Barriers in Implementing Authentic Assessment. Although educators widely recognise authentic assessment as a practical approach to evaluating students' comprehensive competencies, numerous studies reveal that they face several significant challenges when implementing it in chemistry classrooms at both the senior high school and university levels.

1) Time Constraints and Educators' Workload. Many studies report that authentic assessment requires considerably more time for planning, implementation, and evaluation than conventional assessment. Teachers often face pressure from administrative tasks and tight curriculum demands, which limit their ability to implement authentic assessment comprehensively [28, 37]. In higher education, lecturers also struggle with high workloads, especially when providing individual feedback to large groups of students [20].

2) Limited Assessment Literacy and Training. A lack of understanding of authentic assessment concepts and insufficient training opportunities are significant barriers for both teachers and lecturers [12, 29]. Some educators face difficulties in developing valid and reliable rubrics and in distinguishing authentic assessment from traditional testing methods.

3) Insufficient Resources and Facilities. Particularly in high school settings, the lack of laboratory facilities, experimental equipment, and access to technology poses challenges for conducting practice- or project-based assessments [27, 36]. In many cases, laboratories double as classrooms, chemicals are unavailable, and internet access is limited, further complicating digital or virtual assessment.

Educators also face challenges in validating assessment instruments and maintaining objectivity in evaluating portfolios, projects, and peer assessments [22, 35]. Subjectivity can arise due to inconsistent scoring standards and a lack of shared understanding among assessors.

4) Varied Student Readiness and Engagement. Students are often unaccustomed to self-reflection, peer review, and intensive group work. Some students exhibit low motivation, poor time management, or reluctance to participate, particularly in long-term project-based or continuous assessments [24, 32, 38]. Absenteeism and unwillingness to assess peers also present technical barriers.

5) Technical and Digital Challenges. In technology-based assessments, such as e-portfolios or LMS-integrated tasks, technical difficulties – including unstable internet access, limited digital literacy among teachers, and a lack of supporting devices – can hinder implementation [33, 40]. Many schools and universities also lack the infrastructure needed for effective online teaching and assessment.

6) Curriculum Alignment and Formal Evaluation Systems. Another structural challenge is integrat-

ing authentic assessment into curricula that remain heavily focused on written examinations [24, 29]. In many cases, authentic assessment is not yet fully embedded in national or institutional evaluation systems, rendering its use supplementary and experimental rather than standardised.

In summary, the challenges in implementing authentic assessment stem not only from technical issues but also from structural and pedagogical factors. Time limitations, resource constraints, and varying levels of preparedness among educators and students, combined with pressure from conventional educational systems, are among the key barriers. Addressing these challenges requires continuous professional development, curriculum reform, and investment in inclusive and contextual educational infrastructure.

CONCLUSIONS

A systematic review of 25 articles reveals that authentic assessment in chemistry education has been implemented in various forms at both senior high school and higher education levels, including projects, portfolios, inquiry-based experiments, self-assessment, peer assessment, and e-portfolios. These assessments address cognitive aspects, science process skills, scientific attitudes, and students' reflective abilities.

Educators integrate implementation into laboratory-based, project-based, online, and contextual learning environments. Teachers and lecturers play a crucial role in designing assessment instruments, facilitating learning, and providing formative feedback to students. However, challenges such as limited time, resources, assessment literacy, and student readiness remain significant barriers.

Authentic assessment can enhance the quality of meaningful and contextual chemistry learning when educators receive adequate training and when policies and educational infrastructure support its implementation.

Based on the findings of this review, we propose the following recommendations:

1) Enhancing Educator Training. Continuous professional development programs are essential for enhancing the proficiency of teachers and lecturers in authentic assessment, particularly in designing valid instruments, providing formative feedback, and integrating assessments into active learning practices.

2) Developing Adaptive Curriculum Structures. Chemistry curricula at both secondary and tertiary levels should allocate structured space for authentic assessment, not merely as a supplementary tool, but as an integral part of the formal evaluation system.

3) Providing Adequate Facilities and Digital Infrastructure. Educational institutions and policymakers are encouraged to invest in laboratory facilities, internet access, and reliable digital learning platforms to support practice-based and technology-supported assessments.

4) Increasing Student Readiness. Educators should support students through targeted interventions to build readiness for project-based, reflective, and collaborative assessments, including training them in metacognitive strategies and time management skills..

5) Strengthening Contextual Follow-Up Research. Researchers need to conduct further context-specific studies to develop implementation models of authentic assessment aligned with local educational settings and to examine their impact on learning outcomes and 21st-century skills.

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