A Thematic Analysis of Chemistry Teachers' Readiness to Implement Authentic Assessment Integrating the 4C Skills

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Article Info	Abstract
	Teachers play a crucial role in the successful implementation of authentic assessment, particularly within the context of the Merdeka Curriculum, which emphasizes the integration of 21st-century skills, or the 4Cs. This study aims to analyze the readiness of high school chemistry teachers (SMA/MA) in Semarang City to implement authentic assessment integrated with 4C skills, as well as to identify its supporting and inhibiting factors. A qualitative descriptive approach was employed, using thematic analysis supported by triangulation techniques, which included interviews, observations, and document analysis. The participants were selected through purposive sampling of 20 teachers from different schools. Data analysis was conducted through several stages: data transcription, coding, thematic categorization, and drawing conclusions. The findings reveal that chemistry teachers demonstrated a high level of readiness across four aspects: (1) Cognitive: 74% of the assessment tools were complete, indicating a good understanding of authentic assessment; (2) Physical: All respondents were in good health and had strong physical endurance; (3) Psychological: The teachers were motivated and showed strong interest in implementing authentic assessment; (4) Facilities and Infrastructure: On average, the schools had adequate facilities and resources available. Supporting factors included training, infrastructure availability, teacher collaboration, and a solid understanding of assessment concepts. The main obstacles were the lack of advanced training, significant differences in student abilities, limited time, and low technological proficiency among some teachers. These findings are expected to serve as a foundation for strengthening policy and providing continuous professional development to improve the quality of authentic assessments integrated with 4C skills.

INTRODUCTION

Twenty-first-century education is understood as a learning process that prepares students to adapt to technological advancement and global challenges by strengthening core competencies, particularly the 4C skills—*critical thinking, collaboration, communication,* and *creativity* (Rosnaeni, 2021; Zubaidah, 2016; Mardhiyah, dkk., 2021). Critical thinking enables students to analyze information and solve problems in a deep and comprehensive manner (Rahardhian, A., 2022), collaboration supports effective teamwork (Rosyida, dkk., 2023), communication is needed to convey ideas clearly and persuasively (Suryadi, Sopandi, & Sujana, 2024), and creativity helps generate novel ideas and solutions (Suroso, dkk., 2021). Learning assessment refers to the use of evaluation to determine the extent to which students have achieved the intended learning outcomes (Black & Wiliam, 2018), while authentic assessment emphasizes students' ability to apply knowledge and skills in real-life contexts rather than merely recalling theories (Sugiri dan Priatmoko, 2020; Chabeli, Nolte, dan Ndawo. 2021). The PISA 2022 report shows Indonesia's average scores of 359 in *reading literacy* and 383 in *science literacy*, remaining below the OECD averages of 476 (reading) and 485 (science), indicating the need to strengthen higher-order thinking and data- and logic-based problem solving that aligns with the 4C framework. Curriculum change

from the 2013 Curriculum to the Merdeka Curriculum grants teachers greater autonomy to design learning plans based on students' needs and school contexts (Neliwati, 2023), placing assessment planning and implementation in an increasingly strategic position. Learning achievement strongly depends on teachers' competence in selecting appropriate approaches, utilizing learning media, and integrating technology effectively (Rahayuningsih & Muhtar, 2022), along with teachers' roles in shaping character, motivation, and learning autonomy (Lubis, 2020; Gasinets, et. al., 2022), given that teachers play a key role in educational success (Walker, 2019).

Authentic assessment is widely recommended as an approach aligned with twenty-first-century learning because it promotes meaningful, contextualized evaluation that requires students to apply knowledge in realistic situations (Sugiri dan Priatmoko, 2020; Chabeli, Nolte, dan Ndawo. 2021). Implementation may take the form of projects, portfolios, observations, and task-based assessments that enable more comprehensive evaluation of attitudes, knowledge, and skills (Achmad, dkk., 2022). Implementation in practice often faces challenges, especially due to differences between assessment characteristics in the Merdeka Curriculum and those in the previous curriculum, which can lead to confusion and numerous practical questions about assessment execution (Imamuddin & Isnaniah, 2023). The complexity of authentic assessment is also frequently perceived as higher than conventional assessment, requiring greater time and effort during planning, administration, and result processing (Saher, et al., 2022). Such conditions suggest that strengthening teachers' capacity involves not only understanding the concept of authentic assessment but also being ready to operationalize 4C integration in classroom instruments, rubrics, and assessment strategies.

Chemistry as a subject adds specific demands because it involves abstract concepts, learning processes that rely on experimentation, and laboratory skills that require assessment to represent conceptual and experimental aspects in a balanced way (Dzikro & Dwiningsih, 2021). Chemistry teachers therefore need to design assessments that capture not only final learning outcomes but also scientific thinking processes, teamwork, scientific communication, and students' creativity in line with twenty-first-century learning expectations (Rosnaeni, 2021; Zubaidah, 2016). This study focuses on mapping chemistry teachers' readiness to implement authentic assessment integrating 4C skills within the Merdeka Curriculum context and on identifying factors influencing its implementation, so the findings can inform teacher training recommendations, strengthen school-level policies, and support the development of assessment strategies suited to the characteristics of chemistry learning (Rahayuningsih & Muhtar, 2022; Neliwati, 2023; Dzikro & Dwiningsih, 2021).

METHODS

Reseach Design

This study aims to explore chemistry teachers' readiness and to identify factors influencing the implementation of authentic assessment. Accordingly, it adopts a qualitative approach using a descriptive qualitative design. Descriptive qualitative research is used to describe and interpret factual phenomena in depth based on participants' experiences and real-world contexts, without focusing on hypothesis testing (Vaismoradi, 2013; Sugiyono, 2011).

Data Collection

Data were collected through interviews, observations, and documentation from chemistry teachers in public and private senior high schools (SMA/MA) in Semarang City. The participants comprised 20 chemistry teachers from different schools, selected using purposive sampling based on their relevance to the study objectives and involvement in conducting classroom assessment. Semi-structured interviews were employed to allow participants to share experiences and perspectives more freely while remaining aligned with the research focus. Observations were conducted using a checklist-based observation sheet developed from initial indicators to guide systematic field-note recording regarding assessment implementation. Documentation included relevant assessment-related materials, such as lesson plans, assessment instruments, rubrics, and other supporting documents, to strengthen contextual understanding and enrich evidence across data sources.

Data Analysis

The data were analyzed using thematic analysis, an interpretive method for identifying patterns of meaning, organizing data, and clustering them into themes representing the studied phenomenon (Aronson, 2015). The

analysis was conducted inductively and followed thematic analysis procedures described by Braun & Clarke (2006) and Attride-Stirling (2001), including: (a) transcription and repeated reading to achieve in-depth familiarization with the data; (b) initial coding conducted manually and openly to capture meaningful units; (c) grouping related codes into categories to develop themes and sub-themes; and (d) interpreting and drawing conclusions by linking emergent themes to relevant theory and the study aims. To enhance trustworthiness, this study applied data triangulation by comparing information across participants (chemistry teachers from different schools) and cross-checking interview findings with observation and documentation evidence (Susanto, Risnita & Jailani, 2023). In addition, member checking was conducted to ensure that the researcher's interpretations accurately reflected the participants' intended meanings and perspectives.

RESULT AND DISCUSSION

Thematic Analysis Results: Transcription, Coding, and Theme Development

The research data obtained from semi-structured interviews, checklist-based observations, and documentation were first transcribed and then read repeatedly to develop a comprehensive understanding of the context of authentic assessment implementation in chemistry learning. Manual, open coding was conducted to capture meaningful units emerging from participants' statements as well as supporting evidence from observations and documents. The initial codes were subsequently clustered into sub-themes based on similarities in meaning and then synthesized into overarching themes that represent patterns in the field data. The coding process produced 15 codes (A1–A5, B1–B5, C1–C5) reflecting teachers' knowledge and experience, personal conditions, internal drives, and supporting resources. Table 1 presents the list of codes and sub-themes, while Table 2 outlines the resulting thematic structure. The interpretation of the data yielded four main themes: (1) Teachers' Cognitive Readiness, (2) Teachers' Psychological Readiness, (3) Teachers' Personal Readiness, and (4) Readiness of Supporting Infrastructure and Resources. The thematic mapping was applied consistently by positioning C3 (the completeness of authentic assessment instruments) under infrastructure/institutional support, as it more strongly reflects the availability of assessment tools and supporting systems rather than teachers' internal motivation.

Table 1. Coding Framework and Operational Indicators

Code	Sub-theme (Discussion Topic)	Operational Indicators (brief)
A1	Teachers' educational qualifications	Educational background, subject alignment, professional development
A2	Teachers' understanding of authentic assessment	Definition, principles, differences from conventional testing
A3	Experience in implementing authentic assessment	Use of projects, portfolios, performance-based assessment
A4	Preparation of authentic assessment instruments	Rubrics, instruments, worksheets/tasks, scoring guidelines
A5	Understanding of 4C skills	Interpretation of 4C and examples of classroom application
B1	Training in authentic assessment	Participation in training/mentoring programs
B2	Development of authentic assessment instruments	Process of designing rubrics/instruments (individual/collaborative)
B3	Gender	Participant characteristics (profile)
B4	Age	Participant characteristics (profile)
B5	Teachers' physical health	Health/energy condition affecting implementation
C1	Interest	Interest in developing authentic assessment
C2	Motivation	Drive to improve assessment/learning quality
C3	Completeness of authentic assessment instruments	Availability of rubrics, instruments, formats, assessment system
C4	Financial readiness	Funding support, costs for materials, training, supplies, practicum
C5	Availability of learning media at school	ICT tools, laboratory facilities, internet access, LMS, presentation tools

Table 2. Summary of Themes, Codes, and Operational Definitions

Theme	Codes and Sub-themes	Operational Definition of the Theme
Cognitive Readiness (CR)	A1, A2, A3, A4, A5, B1, B2	Teachers' knowledge, experience, and competence in understanding 4C skills and in designing/implementing authentic assessment, including assessment instruments and rubrics.
Psychological Readiness (PR)	C1, C2	Teachers' internal drive—interest and motivation—to implement and further develop authentic assessment integrating 4C skills.
Personal Readiness (PeR)	B5 (B3–B4 as contextual information)	Individual conditions that influence teachers' energy, stamina, and consistency in implementing assessment (e.g., health status and workload).
Infrastructure and Resource Readiness (IRR)	C3, C4, C5	Availability of school facilities and resources that enable authentic assessment to be implemented effectively (e.g., assessment tools, funding, and learning media).

Chemistry Teachers' Cognitive Readiness in Implementing Authentic Assessment Integrating 21st-Century Skills

Teachers' cognitive readiness emerged as a central component in implementing authentic assessment integrating 21st-century (4C) skills. The findings indicate that most chemistry teachers demonstrated an adequate conceptual understanding of authentic assessment principles. This included familiarity with assessment formats such as project-based tasks, portfolios, and performance observation, as well as supporting tools such as rubrics and observation sheets. Most teachers reported participating in Merdeka Curriculum implementation training that included sessions related to authentic assessment development. One participant stated, "I received training on assessment when the Merdeka Curriculum was first implemented, so I understand how to design rubrics or tasks that align with 4C skills." While this suggests foundational knowledge, the depth of understanding varied across teachers, plausibly influenced by differences in training exposure, teaching experience, and collaboration opportunities with colleagues.

Several teachers also described attempts to integrate 4C skills into lesson planning and assessment design—for example, embedding collaboration through group tasks or encouraging creativity through open-ended projects. One teacher explained, "We design lab tasks that assess not only the final results, but also how students discuss and develop solutions together." These accounts suggest that 4C integration was not only recognized conceptually but also enacted in classroom practices. However, uncertainty remained among some teachers regarding how to distinguish authentic assessment from other approaches, particularly higher-order thinking skills (HOTS) items. This is reflected in statements such as, "We are still sometimes confused about the difference between HOTS questions and authentic assessment—are they the same or not?" This indicates a need for more structured conceptual reinforcement and practical guidance so that teachers can design and implement assessment practices that consistently align with authentic assessment principles and 4C-oriented outcomes.

Based on the analysis of instructional documents, the average completeness of authentic assessment instruments developed by teachers reached **74%**, indicating a relatively strong level of preparedness in terms of documented instruments (e.g., rubrics, observation sheets, and explicit indicators related to 21st-century skills). This finding is consistent with Hamdina & Fuadi (2024), who reported that teachers' cognitive readiness substantially supports successful competency-based assessment implementation. Overall, chemistry teachers demonstrated relatively strong cognitive readiness, although continued strengthening through advanced training and sustained professional mentoring remains important.

Chemistry Teachers' Physical Readiness in Implementing Authentic Assessment Integrating 21st-Century Skills

Physical readiness in the context of implementing authentic assessment refers to aspects such as physical stamina, which may be influenced by age, gender, and health status, and which can affect teachers' ability to carry out assessment optimally. The interview results indicate that most teachers felt physically capable of developing

and implementing authentic assessment. This is reflected in one statement: "In terms of physical readiness, God willing, everyone is healthy, and based on teachers' health history data, they have a good medical background. Overall, the findings show that chemistry teachers in senior high schools (SMA/MA) in Semarang City were in good physical condition. This was reflected in several aspects, including the age profile. Most teachers were over 45 years old; however, they still demonstrated strong work performance and did not experience significant physical barriers when implementing authentic assessment. This physical readiness was also supported through observation and interviews, in which students reported that teachers attended classes consistently in healthy condition and taught with enthusiasm. In addition, all teachers were reported to have stable health histories, with no chronic illnesses that could interfere with their professional duties. This condition serves as a strength in implementing authentic assessment in the classroom, as teachers are physically present and able to take an active role in planning, conducting, and evaluating learning activities. Optimal physical readiness is also an important foundation for sustaining meaningful and adaptive learning in line with 21st-century demands. Therefore, teachers' physical readiness to implement authentic assessment can be categorized as very good. Although several teachers were aged 45 and above, their performance did not decline, and they remained responsible for planning and implementing authentic assessment oriented toward 21st-century skills in schools.

Chemistry Teachers' Psychological Readiness in Implementing Authentic Assessment Integrating 21st-Century Skills

Teachers' psychological readiness is an equally important factor in the successful implementation of authentic assessment. This aspect includes teachers' motivation, interest, self-confidence, and mental preparedness in responding to curriculum change and to assessment approaches that are more complex and require creativity. The interview findings indicate that most chemistry teachers in public and private senior high schools (SMA/MA) in Semarang City have high motivation to implement authentic assessment. This motivation is driven by the awareness that authentic assessment can provide a more comprehensive picture of students' competencies, particularly 21st-century skills such as critical thinking, creativity, collaboration, and communication (4C). One teacher stated, "I feel more challenged to develop assessment instruments that do not only test memorization, but also students' thinking skills and teamwork."

In addition to motivation, teachers' interest in instructional innovation also supports psychological readiness. Teachers who actively participate in training and workshops on authentic assessment tend to demonstrate stronger mental readiness in dealing with technical and conceptual challenges. This is also reflected in data triangulation, where teachers who attended training reported greater confidence in designing and implementing authentic assessment. Nevertheless, teachers also faced psychological challenges, such as anxiety about mastering the technology required for digital-based assessment and time pressure when developing complex assessment tools. Several teachers acknowledged difficulties in balancing workload between teaching responsibilities and authentic assessment practices that require more intensive preparation. One participant noted, "Sometimes I feel overwhelmed by administrative tasks and also having to prepare assessments that are truly meaningful." Moreover, school culture and leadership support were found to influence teachers' psychological readiness. Schools that provide appreciation and support for innovative practices tend to strengthen teachers' confidence and enthusiasm to implement authentic assessment.

These findings confirm that psychological readiness is a key factor influencing the success of authentic assessment implementation. High motivation and interest serve as essential capital, while psychological barriers such as anxiety and time pressure need to be addressed through advanced training, mentoring, and supportive school management. In line with achievement motivation theory, a positive environment can enhance teachers' mental readiness to innovate in assessment practices and improve performance at school (Dewi, R., 2018; Putra & Negara, 2021). Overall, chemistry teachers' psychological readiness in Semarang City is generally good, yet it needs further strengthening, particularly in managing work-related stress and in utilizing technology for authentic assessment.

Infrastructure and Facilities Readiness in Supporting the Implementation of Authentic Assessment Integrating 21st-Century Skills

Infrastructure and facilities readiness is a crucial aspect that supports the effectiveness of implementing authentic assessment, particularly when it is integrated with 21st-century skills such as the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity). Adequate facilities enable teachers to design, conduct, and

evaluate assessment more optimally. Observation data indicate that most schools in Semarang City have provided facilities that sufficiently support the implementation of authentic assessment. These include the availability of assessment tools such as rubrics, evaluation instruments, interactive learning media, and information technology that supports assessment processing and reporting. Several teachers reported that the presence of computer laboratories and internet access at school facilitates the use of digital assessment applications, allowing assessment to be conducted more flexibly and in ways that are more engaging for students.

An analysis of the *Modul Ajar* documents also showed that approximately 68% of the authentic assessment plans developed by teachers specified particular tools and learning media requirements. In practice, however, classroom implementation often required adjustments because the availability of tools did not always match what had been planned. As a result, some teachers modified activities or simplified the form of assessment, although they recognized that this could reduce the authenticity of the assessment and therefore required careful consideration. In addition, physical facilities such as comfortable classrooms and dedicated spaces for practicum-based assessment are highly supportive of various types of authentic assessment, including projects, portfolios, and performance assessment. This aligns with previous research reporting that complete facilities contribute positively to the quality of assessment implementation (Nasikhah & Sumarsono, 2024). One teacher stated, "Our school already has a projector and internet access, so we can assign video presentations or online discussions as a form of communication-skills assessment." This statement reflects how available facilities can support diverse assessment formats that align with 21st-century approaches. Furthermore, observations in several schools showed that flexible learning spaces were also provided and were adequate for experiments or collaborative projects, both of which are integral to authentic assessment. Nevertheless, challenges related to infrastructure and facilities were still identified in some schools, particularly private schools with limited budgets. Several teachers highlighted inadequate technological resources, such as a limited number of computers and unstable internet connections, which hinder the implementation of digital-based assessment. These constraints become especially problematic when assessment requires the use of digital media or application-based evaluation.

School financial capacity was also found to be an important determinant in fulfilling infrastructure and facility needs. Schools with sufficient funding tend to provide more complete and innovative facilities, while schools with limited funding rely heavily on teachers' creativity and whatever resources are available. This condition requires attention from education authorities and relevant stakeholders so that infrastructure provision can be improved and distributed more equitably. From the perspective of managerial support, schools that prioritize infrastructure development and allocate specific budgets for training and the procurement of authentic assessment tools tend to show more substantial improvement in assessment implementation. A participatory approach between school management and teachers also appears to be effective in ensuring that infrastructure readiness aligns with the practical needs of authentic assessment. In conclusion, infrastructure and facilities readiness generally supports the implementation of authentic assessment integrating 21st-century skills in schools across Semarang City. However, continuous improvement is still needed—particularly in information technology and financial support—so that all schools can implement authentic assessment optimally and more evenly.

Supporting and inhibiting Factors in Implementing Authentic Assessment

Supporting factors are essential elements that influence the smooth implementation and success of chemistry teachers in applying authentic assessment. The findings indicate several key factors that strengthen teachers' readiness and the execution of authentic assessment in schools. First, regular training and dissemination activities related to authentic assessment and the Merdeka Curriculum help teachers understand the concepts, techniques, and procedural steps of assessment implementation. Such training not only expands teachers' knowledge but also strengthens their motivation and cognitive readiness to implement authentic assessment appropriately. Second, the availability of adequate facilities and infrastructure—such as assessment tools, supporting technologies, and a conducive learning environment—makes it easier for teachers to prepare and conduct assessment. Schools that provide more complete facilities tend to enable more effective assessment implementation and create more engaging learning experiences for students. Third, cooperation and collaboration among teachers play an important role in facilitating the exchange of experiences and strategies for implementing authentic assessment. Teacher group discussions and peer mentoring help address practical challenges and improve the overall quality of assessment practices. Fourth, teachers' understanding and mastery of authentic assessment concepts and 21st-century (4C) skills serve as a primary foundation for implementing assessment effectively. Teachers who have stronger mastery of these areas tend to be more confident and creative in designing assessment instruments and adapting them to students' characteristics. Overall, these supporting factors are

interconnected and collectively contribute to the implementation of authentic assessment that aligns with curriculum expectations and the learning needs within the *Merdeka Belajar* era.

At the same time, several inhibiting factors were identified. Unequal access to training and dissemination resulted in limited guidance for some teachers, leading to ongoing difficulties in applying new assessment approaches. Large class sizes and diverse student abilities increased the time and effort required to adapt tasks and scoring processes. Limited competence in information technology constrained teachers' ability to utilize digital tools that could otherwise improve efficiency and accuracy. Finally, limited instructional time combined with administrative workload reduced teachers' capacity to design and implement authentic assessment meaningfully. These constraints are broadly consistent with Hamdina & Fuadi (2024), indicating the importance of coordinated solutions through equitable training, sustained mentoring, improved facilities, and stronger workload/time-management support.

CONCLUSION

This study indicates that chemistry teachers in public and private senior high schools (SMA/MA) across Semarang City have generally demonstrated good readiness to implement authentic assessment integrating 4C skills within the Merdeka Curriculum. This readiness is reflected in four key aspects. Cognitively, teachers show a solid understanding of authentic assessment and have prepared assessment instruments with a high level of completeness (74%). Physically, teachers' health conditions support consistent implementation of authentic assessment. Psychologically, teachers demonstrate strong interest and motivation to apply authentic assessment practices. In terms of infrastructure, schools have generally provided adequate facilities to support the implementation of such assessment. The study also identifies factors that influence authentic assessment implementation. Supporting factors include training and dissemination related to authentic assessment, the availability of adequate facilities and resources, collaboration among teachers, and teachers' mastery of authentic assessment concepts and procedures within the Merdeka Curriculum. In contrast, inhibiting factors include uneven access to training, large class sizes with diverse student abilities, limited time and administrative workload, and some teachers' limited competence in using information technology for assessment. Overall, although chemistry teachers' readiness is generally strong, further strengthening is still required through continuous professional development, sustained mentoring in developing instruments and rubrics, improved time and workload management strategies, and enhanced competence in technology-supported assessment. Strong managerial support from schools and coordinated support from local education authorities are also essential to ensure that the implementation of 4C-integrated authentic assessment becomes more optimal and more equitable across schools.

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