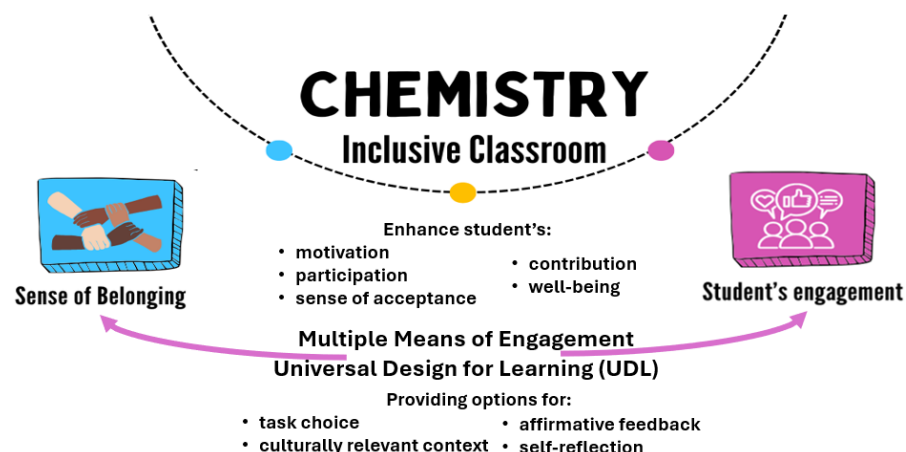


Fostering belonging and engagement in inclusive chemistry classrooms: teachers' experiences through a universal design for learning framework

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Abstract

Engagement and a sense of belonging are essential to inclusive education, particularly for students with education needs and disabilities (SEND) in chemistry classrooms. This study investigates how secondary school chemistry teachers in Indonesia apply the Multiple Means of Engagement (MME) principle of the Universal Design for Learning (UDL) framework to enhance participation and inclusion for students with SEND. Employing a descriptive qualitative approach, data were gathered through in-depth interviews with 11 experienced chemistry teachers and were analyzed thematically. The findings reveal that teachers adopted strategies such as offering task choices, integrating culturally relevant contexts, providing affirming feedback, and encouraging self-reflection. These practices were perceived to strengthen students' motivation, participation, and sense of belonging. Nonetheless, implementation was uneven, constrained by limited conceptual understanding and institutional barriers. The study concludes that UDL-informed engagement strategies have the potential to foster both cognitive and affective inclusion and highlights the importance of professional development that bridges global pedagogical theory with local classroom realities.



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Highlights

- Contextualized application of UDL in the developing country.
- Rich pedagogical insights from teacher voices.
- Practical implications for inclusive chemistry

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1. Introduction

Inclusive chemistry education emphasizes the importance of creating learning environments that support all students, including those with special education needs and disabilities (SEND). As a discipline, chemistry involves cognitive content, laboratory practice, problem-solving, and collaborative work (American Chemical Society; Niazi *et al.*, 2018; Side *et al.*, 2024), all of which require visual, motor, and communication skills. These characteristics present unique challenges for students with SEND, especially when chemistry instruction is not designed with adaptive and flexible pedagogical approaches. Inclusive chemistry education, therefore, is not merely about allowing students with SEND to be physically present in the classroom. It ensures they can access, comprehend, and actively engage in the learning process (Okolo and Diedrich, 2019; Roberts *et al.*, 2024; Wulayalin and Suprihatiningrum, 2023).

In practice, however, many students with SEND continue to face significant barriers to accessing meaningful science learning experiences. These challenges are not simply rooted in individual limitations, but more fundamentally in instructional structures that are not universally designed or responsive to diverse learner needs (Basham *et al.*, 2020; CAST, 2018). The lack of accommodation in instructional delivery, inflexible assessment methods, and limited teacher training in inclusive pedagogy remain key factors contributing to exclusion in science classrooms, including those of chemistry. Several studies have found that students with SEND are less likely to pursue advanced science courses due to previous negative experiences marked by obstacles and disempowerment (James *et al.*, 2019; Yamamoto *et al.*, 2022). To address these issues, inclusive chemistry education must be grounded in a universal design approach, such as Universal Design for Learning (UDL), which enables all students, regardless of their characteristics or needs, to participate meaningfully and achieve equitable learning outcomes (Meyer *et al.*, 2014).

A sense of belonging and engagement are foundational to creating truly inclusive learning environments. Belonging refers to students' feelings of being accepted, valued, and recognized as part of the school community (Erdoğdu, 2019; Hassard *et al.*, 2024; Slaten *et al.*, 2016), while engagement encompasses their active participation, attention, and emotional involvement in academic and social activities (Erdoğdu, 2019; Slaten *et al.*, 2016). These two constructs are deeply interconnected and significantly influence educational achievement, mental health, and student well-being, especially for students from marginalized backgrounds, including those with SEND (Arslan, 2021).

Studies have shown that students with a strong sense of belonging are likelier to possess intrinsic motivation, positive attitudes toward school, and greater resilience in facing academic challenges (Allen and Bowles, 2012; Osterman, 2000). Engagement, whether behavioral, emotional, or cognitive, serves as a critical mediator of academic success, particularly in inclusive classrooms characterized by diverse learning profiles (Chhetri and Baniya, 2022; Li and Xue, 2023; Wang and Degol, 2016). Unfortunately, students with SEND frequently experience social exclusion, which undermines their sense of belonging and, consequently, their engagement (Arney and Rozek, 2024; Brown *et al.*, 2025). Thus, fostering belonging and engagement is not merely a pedagogical strategy but a moral and social imperative for achieving educational equity in inclusive classrooms (Arney and Rozek, 2024; Hall, 2020; UNESCO, 2020, PREPRINT). One robust framework for supporting student belonging and engagement in chemistry education is UDL.

UDL is a research-based pedagogical approach designed to improve instructional quality by accommodating diverse learning needs. Grounded in cognitive science, neuroscience, and education findings, UDL asserts that there is no one-size-fits-all approach to learning (CAST, 2018). It aims to ensure that all students, regardless of background, ability, or disability, can fully access and participate in learning through its three core principles: Multiple Means of Engagement, Multiple Means of Representation, and Multiple Means of Action and Expression (Meyer *et al.*, 2014).

The principle of Multiple Means of Engagement (MME) is particularly relevant in inclusive education because it emphasizes the importance of recruiting interest, sustaining effort and persistence, and supporting self-regulation (CAST, 2018). Initially, educators are encouraged to provide learners with options, connect learning to culturally relevant experiences, and establish emotional safety to stimulate authentic interest (Rao *et al.*, 2021). Next, learners are supported in setting meaningful goals, engaging in collaborative tasks, and receiving constructive feedback to maintain sustained effort. Ultimately, students are guided in developing self-awareness, reflection, and emotional regulation, crucial for sustained, self-directed learning.

Research has shown that implementing MME not only enhances participation among students with SEND but also offers universal benefits for all learners, including those from minority backgrounds or with diverse learning styles (Basham *et al.*, 2020; Lowrey *et al.*, 2017). In this way, UDL is not simply an intervention strategy. It represents a foundation for equitable and transformative instructional design. MME encourages educators to create emotionally safe and culturally relevant learning environments by offering choice, fostering collaboration, and building meaningful relationships (Rao *et al.*, 2021).

Studies have consistently shown that implementing MME fosters engagement, improves attendance, reduces behavioral issues, and strengthens students' sense of belonging, especially in diverse classrooms (Lowrey *et al.*, 2017; Moleko, 2021). In science education, where cognitive and technical demands are high, MME offers a bridge to make learning more inclusive, meaningful, and transformative for all learners (Qu and Cross, 2024).

While UDL has been widely promoted as a pedagogical model for inclusive education, most existing literature focuses on conceptual frameworks, curriculum design, or technology integration (Basham *et al.*, 2020; Rao and Meo, 2016). Empirical studies that explore teachers' experiences in implementing UDL, particularly MME, in inclusive chemistry classrooms within developing countries like Indonesia are still scarce. Existing research primarily centers on the Global North, assuming relatively stable educational infrastructures and policy environments (Han and Lei, 2024).

Moreover, the pedagogical challenges in science (including chemistry) education are compounded by abstract content, hands-on experimentation, and conventional teaching approaches that often lack flexibility (Aidoo, 2024; Morris, 2025). These challenges are even more pronounced in Indonesia, where inclusive practices remain limited and teachers often receive minimal training in accommodating students with SEND. While global scholarship has highlighted the potential of the MME principle within the UDL framework, no in-depth study has examined how chemistry teachers in Indonesia specifically foster engagement and belonging for students with SEND through real-world and classroom-based strategies. This research is therefore urgent to address both the scarcity of empirical evidence in the Indonesian context and the pressing need to translate inclusive pedagogical theory into localized classroom practice.

The study identifies strategies and explores the broader context, challenges, and teacher reflections involved in designing inclusive and meaningful learning experiences. In addition, this study aims to enrich the UDL literature in Global South contexts, providing practical and policy-relevant guidance for advancing inclusive pedagogy tailored to Indonesia's diverse educational setting.

To achieve this, the study addresses the following research questions:

1. How do chemistry teachers in secondary schools understand and implement the MME principle in inclusive science classrooms?
2. What strategies do teachers use to build interest, sustain effort, and support self-regulation among students with SEND in chemistry education?
3. What challenges and reflections do teachers experience while fostering engagement and belonging through MME?

This study makes two main contributions. Theoretically, it expands our understanding of UDL implementation in Global South contexts, particularly in chemistry education. Practically, it provides field-based insights that can inform teacher training programs, school policies, and adaptive instructional planning for diverse learners.

2. Method

2.1. Research design

This study employed a descriptive qualitative approach using a collective case study design to understand inclusive pedagogical practices in a contextual and in-depth manner (Merriam and Tisdell, 2016; Stake, 2006). This design was selected to capture the complexity of teachers' experiences implementing the Multiple Means of Engagement (MME) principle of the Universal Design for Learning (UDL) framework within inclusive chemistry classrooms. The exploratory study aims to uncover processes, strategies, and challenges that have not been extensively examined in the Indonesian context.

2.2. Participants and research context

The study involved 11 secondary school chemistry teachers from various schools in the Special Province of Yogyakarta. Participants were selected through purposive sampling based on two main criteria: (1) having at least one year of experience teaching students with SEND, and (2) willingness to participate in in-depth interviews. The participants represented diverse types of institutions, public, private, and religious schools, reflecting a range of educational settings and resource availability (see Table 1). All participants provided informed consent before data collection. Although the number of participants was relatively small, it was sufficient to achieve thematic saturation, as recurrent patterns were consistently identified across the interviews and no substantially new themes emerged during the later stages of analysis.

2.3. Data collection technique

Primary data were collected through semi-structured in-depth interviews lasting approximately 60 to 90 minutes. The interview guide was developed based on the three core areas of the MME principle, i.e., strategies for recruiting interest, sustaining effort and persistence, and supporting self-regulation. Interviews were audio-recorded using a digital voice recorder, and

contextual observations were documented to complement and enrich the interpretation of the data. To enhance validity, follow-up communications were conducted with several participants to clarify any points. All data were handled with strict adherence to confidentiality and ethical research principles. This study draws primarily on teacher interviews as the main source of data, and while this provides rich insights into pedagogical practices, the absence of additional perspectives, such as classroom observations or student voices, may reduce opportunities for deeper triangulation and complementary insights into how engagement and belonging are enacted in practice.

2.4. Data analysis techniques

The interview data were analyzed using reflective thematic analysis as outlined by (Braun and Clarke, 2006), involving five stages: (1) familiarization with the data, (2) open coding, (3) identification of initial themes, (4) review and refinement of themes, and (5) construction of thematic narratives. Coding was conducted manually and validated through peer debriefing to ensure the reliability of interpretation. Themes were developed directly about the three domains of the MME principle and were contextualized through relevant literature to allow for analytical generalization (Yin, 2014).

2.5. Ethical consideration

This study received ethical clearance from the internal review board of the researchers' affiliated university. All participants were provided with information regarding the study's purpose, procedures, their right to withdraw, and data confidentiality. Names of participants and institutions were anonymized to protect their identities.

Table 1. Participant profiles.

Participant	Gender	School	Years of Teaching Experience SEND students
Mitchel	Female	School A	> 5 years
Willow	Female	School B	± 24 years
Melanie	Female	School C	± 1 year
Miles	Male	School D	> 5 years
Emily	Female	School E	> 4 years
Kyle	Female	School F	> 2 years
Rose	Female	School G	> 2 years
Nancy	Female	School H	> 1 year
Max	Male	School I	± 4 years
Diana	Female	School J	± 4 years
Nadia	Female	School K	> 1 year

Source: Elaborated by the authors.

3. Results and discussion

3.1. Teachers' understanding and implementation of the MME principle

Interviews with 11 secondary chemistry teachers revealed that most recognized the importance of creating a learning environment that motivates and engages students. However, their understanding of the MME principle remains largely implicit. Teachers tended to associate student engagement with contextualized instruction and general adaptation strategies, without explicitly linking their practices to the UDL framework.

For instance, Mitchel, a teacher at *School A*, shared:

I usually give students options for their assignments. If they're working on a project, they can choose whether to create a poster, produce a video, or deliver a live presentation. They get more excited when they can align the task with their interests.

Similarly, Diana from *School J* emphasized the importance of involving students in decision-making:

I let the students help decide group rules or choose how they want to present. When they take part in the decisions, they feel more responsible and engaged.

Melanie from *School C* shared a classroom practice that showed potential for developing self-awareness:

We tried a reflection activity after lab work, students wrote about their experiences and challenges. It helped them recognize their strengths and weaknesses.

Although several teachers had adopted the MME principle, many still acknowledged a lack of specific strategies to support students' self-regulation and foster sustained engagement, particularly for learners with SEND.

When it comes to helping students manage their study time or recognize their emotions, I haven't developed any specific strategy for that. I usually focus more on helping them complete their tasks first.

—Miles, *School D*

Some teachers attributed this gap to limited conceptual knowledge and the absence of formal training related to UDL:

I'm not sure how to help students regulate themselves, like designing their own learning targets. Should I give them reflection tasks or special exercises? I've never really tried that. I've never been trained for that.

—Emily, *School E*

Another teacher shared that she only began to realize the importance of self-regulation after engaging in reflective discussions with peers:

All this time, I thought it was enough if students understood the material. However, I now realize they also need support in recognizing their own strengths and challenges. I've started thinking about having regular reflection sessions, though I'm still not sure how to design them.

—Willow, *School B*

These findings suggest that many teachers already incorporate elements of MME, particularly in offering choices and creating supportive learning environments. However, strategies related to sustaining effort and supporting self-regulation are not consistently applied, and most teachers have not developed structured approaches to these dimensions.

This phenomenon aligns with the findings of some studies (Almumen, 2020; Alquraini and Rao, 2020; Capp, 2020; Cumming and Gilanyi, 2023; Israel *et al.*, 2022; Markou and Diaz-Noguera, 2022), which have found that while teachers often adopt inclusive practices, they may lack formal training or a conceptual foundation in UDL. The absence of professional development and limited documentation of UDL implementation at the school level further widens the gap between theory and classroom practice.

The study highlights the urgent need for structured, UDL-based professional development that emphasizes the MME principle. Teachers should be encouraged not only to apply inclusive strategies but also to reflect on the pedagogical reasoning behind them critically. Integrating MME into teaching supervision and lesson planning, particularly within the context of Indonesia's *Kurikulum Merdeka*, could strengthen both understanding and practice. Additionally, fostering a culture of reflective teaching among educators is essential so that inclusive practices are not just intuitive but grounded in intentional, measurable instructional design.

3.2. Teacher strategies for fostering interest, persistence, and self-regulation in students with SEND

3.2.1. Recruiting interest: generating student motivation

Teachers in this study adopted various approaches to ignite interest among students with SEND. The most common strategies included offering task options, connecting lesson content to students' everyday lives, and incorporating interactive technology.

If I let students choose, whether it's a video, oral presentation, or poster. They become more enthusiastic. Deaf students especially prefer visual formats like posters or videos, which help boost their confidence.

—Mitchel, *School A*

I try to vary the activities, short reports, short videos, vlogs, oral presentations, posters. It gives students different learning experiences beyond just lab work or lectures.

—Rose, *School G*

For topics like acids and bases, I let students choose creative projects like making magic boxes, posters, or film rolls. It keeps them engaged.

—Diana, *School J*

Blind students often enjoy group work because it keeps them active and socially connected. I once asked if they preferred group or independent work, and they said that group work helped them feel included. That said, I still haven't found an appropriate alternative for lab work. Usually, I introduce them to lab tools and assign replacement tasks. I wish I knew how to offer equitable hands-on experiences.

—Kyle, *School F*

When we discussed acids and bases, I connected them to household cleaning products. The students immediately related, especially those who help their parents at home.

—Emily, *School E*

With the new curriculum, we're expected to be more contextual. I integrate science topics into Pancasila Project activities, like making scented candles or liquid fertilizer. The students clearly enjoy these more than traditional lessons.

—Nadia, *School K*

To increase motivation, I often start with mind-mapping. The visuals get them curious and make it easier to dive into the topic.

—Emily, *School E*

I like using Google Classroom. Students, especially those who are Deaf, can submit answers in writing without pressure. They feel more included that way.

—Rose, *School G*

Instead of writing paper-based reports, I ask students to design posters in Canva for their projects. The results are impressive. For assessments, I also use tech tools like Quizizz and Kahoot—they enjoy those a lot more.

—Max, *School I*

The strategies mentioned by participants align with the findings of (Lowrey *et al.*, 2017), who emphasized that offering student choice and connecting content to personal experiences can significantly enhance engagement, particularly for students with SEND. Similarly, Fleming (2023) found that digital UDL tools not only increase accessibility but also foster a sense of emotional safety and inclusion.

3.2.2. Sustaining effort and persistence

Teachers reported designing clear learning objectives, giving constructive feedback, and using problem-based learning tasks to support students in maintaining focus and persistence.

At the beginning of a lesson, I explain why the topic is relevant, like why understanding solutions matters in daily life. It helps students take the lesson more seriously.

—Max, School I

Setting objectives for blind students is difficult. It takes time to understand their learning styles and strengths. But by the time I figure that out, the academic year ends, since they usually only take science in 10th grade before switching to social studies.

—Kyle, School F

I give voice note feedback to students with low vision. They like that they can reply to it as needed. For Deaf students, I use written notes instead.

—Emily, School E

I asked students to imagine building a water filter from recycled materials. In group work, students with disabilities are given specific roles, like recording results or designing posters, so they feel they're contributing meaningfully.

—Melanie, School C

The findings highlight various strategies teachers employ to support students' ability to maintain focus and effort throughout the learning process. These strategies represent thoughtful, if sometimes improvised, attempts to ensure students stay cognitively and emotionally invested in learning. Teachers like Max underscore the motivational value of relevance framing, making explicit connections between scientific concepts and students' real-life contexts. This approach is consistent with motivation theories, which suggest that relevance enhances perceived task value and persistence (Gan *et al.*, 2023; Umarji *et al.*, 2021). Students who understand why something matters are more likely to sustain effort, even when the content is challenging.

At the same time, Kyle's statement highlights the temporal and curricular limitations of inclusion in secondary science. Her difficulty in identifying and responding to the learning profiles of blind students often led to them being placed on a different track the following year. This has significant implications for sustaining effort, as students not afforded enough time or continuity in learning may not develop the deeper engagement necessary for long-term academic interest (Roberts *et al.*, 2024).

Emily's use of differentiated feedback modalities, such as voice notes for low-vision students and written summaries for Deaf students, reflects an authentic application of flexible communication aligned with UDL principles. Her practice illustrates how adapting the form of feedback to students' sensory preferences can promote clarity, autonomy, and emotional safety, factors known to contribute to persistent effort (Yang *et al.*, 2022).

Melanie's example of problem-based learning and assigning meaningful group roles shows how inclusion in collaborative tasks can foster both social belonging and sustained participation. By ensuring that students with SEND are not only present but actively contributing, Melanie promotes situated value, students perceive their input as essential to the group's success, which enhances commitment and reduces disengagement. This echoes findings from (Carter *et al.*, 2016) who argue that roles that highlight competence, not just compliance, are key to genuine inclusion.

Collectively, these narratives reveal that while teachers are taking important steps to sustain student effort, their practices often emerge from personal intuition or reactive adjustments rather than formalized inclusive training. As such, there is a

critical need for systematic support, including professional development that helps teachers integrate persistence-supportive strategies into intentional lesson design, particularly in chemistry contexts where students with SEND remain underrepresented and under-supported.

On the other hand, many teachers acknowledged that they had not developed differentiated learning objectives for students with SEND.

Honestly, I hadn't thought about setting specific goals for students with disabilities. I've always used general objectives. But maybe it would help them more if the goals were tailored.

—Willow, School B

I usually write one set of objectives for the whole class. I assume students will adapt at their own pace. But now I realize that students with special needs might benefit from more specific targets.

—Nancy, School H

Differentiated objectives? I don't think I've ever made separate ones. Not because I don't care — it's just not something we were trained to do. We need clear guidelines for that.

—Miles, School D

For me, success has always meant covering the curriculum. I never really questioned if my objectives worked for everyone. But I'm starting to see that students with disabilities might need goals that match their pace and capacity.

—Max, School I

Many teachers in this study acknowledged that they had not developed differentiated learning objectives for students with SEND. The sentiments from Willow, Nancy, Miles, and Max suggest that differentiation is often overlooked, not due to a lack of care, but rather due to limited training and a systemic focus on standardized outcomes.

This gap highlights a key tension in inclusive education: while students with SEND are present in mainstream classrooms, the curriculum often remains undifferentiated. According to the UDL framework, clearly defined, individualized goals are essential for fostering engagement and providing equitable access to learning (CAST, 2018). Without them, students risk becoming passive participants, with limited opportunities to experience success at their own pace (Roberts *et al.*, 2024). Findings of this study are consistent with (Basham *et al.*, 2020), who note that a lack of individualized goals can hinder self-determined learning. (Gheyssens *et al.*, 2023) also stress the importance of clarity and differentiation to sustain motivation in inclusive classrooms.

3.2.3. Self-regulation: supporting learners' autonomy

While self-regulation strategies were less commonly applied, some teachers implemented reflective practices, informal counseling, and time management skills.

After each project, I give students time to reflect: What went well? What was challenging? They write it down, and I use it to identify who might need more guidance.

—Melanie, School C

I often serve as someone they confide in. Students with disabilities talk to me about their fatigue and fears. I try to help them plan strategies for studying more effectively.

—Nadia, School K

Maybe because I'm a senior teacher, Deaf students often come to me to share their struggles. I suggest ways to overcome their challenges, and sometimes they come back to tell me they've made progress.

—Willow, School B

I teach them how to break down tasks. For big assignments, I ask them to create a timeline. Then we discuss it together.

—Diana, School J

Compared to studies like (Rao *et al.*, 2021), these strategies remain basic. In their research, self-regulation involved explicit metacognitive instruction and tech-based support systems. Nonetheless, the initial steps taken by teachers in this study show promising potential to evolve into more structured approaches.

These findings reaffirm that teachers have considerable potential in implementing MME, even though their efforts are still in the preliminary stage. The lack of coherence in strategy and the absence of a formal framework indicate that current engagement practices are more experience-based than pedagogically planned (Han and Lei, 2024). This echoes (Lambert *et al.*, 2023), who found that teacher training in UDL within Global South contexts remains fragmented and insufficiently institutionalized. Overall, the teachers' approaches reflect elements of student-centered pedagogy and responsive teaching. However, formal training programs, shared reflective spaces among teachers, and systemic support from schools and local governments are necessary to ensure that inclusive learning is both sustainable and scalable.

3.3. The impact of MME implementation on students' sense of belonging and engagement

While much of this study has focused on teacher strategies aligned with the MME principle of UDL, it is equally important to examine their perceived and potential impact on students' sense of belonging and learning engagement, particularly among learners with SEND.

Findings from teacher narratives suggest that even partial and intuitive application of MME strategies, such as offering learning choices, building culturally relevant content, and encouraging reflection, has fostered greater emotional involvement and social inclusion for students who often feel marginalized. Teachers observed that students became more responsive, motivated, and confident when given opportunities to make decisions, collaborate, and see their identities reflected in classroom practices. For example, Willow reported that students with visual or hearing impairments reportedly became more participative when group work was structured to include meaningful roles or when assignments were presented through accessible formats.

These teacher reflections align with the study of (Wu and Dong, 2024; Shernoff, 2013) who emphasized that student engagement is most effectively cultivated in environments that provide both emotional security and opportunities for autonomy. Similarly, research by (Erdoğan, 2019) and (Stremfel *et al.*, 2024) underscores that a sense of belonging in school is not merely defined by physical presence but by the extent to which students feel acknowledged, respected, and included as meaningful participants within the learning community.

Importantly, fostering belonging through MME is not a by-product, but a purposeful pedagogical outcome. When teachers provide varied pathways for interaction and learning expression, they signal to students, especially those with SEND, that they are rightful participants in the academic space (Arslan, 2021; Slaten *et al.*, 2016). This perception of inclusion, in turn, increases emotional investment, persistence, and self-directed behavior, as shown in studies by (Hall, 2020).

Nevertheless, in this study, while teachers observed improvements in student participation, few systematically assessed how their MME-informed practices impacted students' sense of belonging. This highlights a broader gap in inclusive education: engagement is often evaluated in terms of behavioral

compliance, rather than student-centered indicators such as emotional safety, opportunities to express one's voice, and the development of learner agency, that is, students' capacity to make meaningful choices and take ownership of their learning.

This finding reinforces the call for teacher professional development that not only introduces UDL but also helps educators understand how engagement practices shape identity and community. When MME is implemented with this awareness, it can transform chemistry classrooms into spaces where all students, regardless of ability, feel that they belong, matter, and are capable of success.

3.4. Linking multiple means of engagement to a sense of belonging

Implementing the MME principle in this study was found to have a positive, though often implicit, impact on students' sense of belonging. This section explains how each domain of MME, when practiced intentionally, contributes to fostering a sense of belonging, particularly for students with SEND.

3.4.1. Recruiting interest and psychological inclusion

When teachers offer choices in assignments, relevant learning contexts, and emotionally safe learning environments, they activate not only cognitive engagement but also students' sense of significance. Research indicates that autonomy-supportive practices, such as allowing students to choose the format of their output or relate content to their own lives, contribute to psychological ownership, which is closely tied to feelings of belonging (Siacor *et al.*, 2024; Wu and Dong, 2024).

In this study, students who were given options, such as presenting through video or designing posters, were described by teachers as more motivated and socially engaged. These forms of personalization make students feel recognized as individuals whose preferences and voices matter, reinforcing the perception that they are legitimate and valued members of the classroom community (Daoayan Biaddang and Caroy, 2024; Ferlazzo, 2017; Patzak and Zhang, 2025; Yang *et al.*, 2022).

3.4.2. Sustaining effort and communal purpose

The second MME component, sustaining effort and persistence, contributes to belonging by fostering relational trust and collective efficacy in learning. When teachers provide clear, meaningful learning goals and regular feedback, especially tailored for students with SEND, they communicate care, high expectations, and inclusion (Hall, 2020; Osterman, 2000).

Teachers in this study reported that students responded more positively when they understood why they were learning something and how it connected to real life. Collaborative tasks, especially when students with SEND were assigned meaningful roles, helped them feel needed by their peers. This supports prior findings that inclusion in peer-based activities and affirmation of effort contribute to feelings of classroom connectedness (Wilkins *et al.*, 2023).

3.4.3. Supporting self-regulation and identity development

The third MME domain, supporting self-regulation, plays a vital role in helping students construct a stable sense of identity within the classroom. Teachers who encourage students to reflect on their learning, manage their goals, or regulate their emotions provide them with tools not just for academic success, but also for internalizing their role within the learning community (Arslan, 2021).

Reflection activities described by teachers, such as journaling after experiments or timeline planning for large assignments, enable students to see themselves as capable, growing participants in the classroom. This fosters self-efficacy, which in turn nurtures belonging through competence (Moleko, 2021; Slaten *et al.*, 2016).

These findings demonstrate that the intentional implementation of MME strategies not only enhances student engagement but also directly cultivates the emotional and social conditions necessary for a sense of belonging. For students with SEND, who are often at a higher risk of social exclusion, this alignment between instructional design and emotional inclusion is particularly crucial. However, for these impacts to be fully realized, teachers must move from intuitive practice to intentional design. Professional development programs should therefore help teachers make explicit how engagement strategies can shape students' sense of membership, identity, and agency in the classroom.

3.5. Challenges and reflections on MME implementation

3.5.1. Challenges in classroom implementation

Teachers in this study faced various obstacles in implementing the MME principle to support students with SEND in chemistry classrooms. These challenges can be categorized into three main areas: (1) limited conceptual understanding, (2) resource constraints, and (3) institutional resistance.

3.5.1.1. Limited conceptual understanding

Most teachers admitted that they had never received formal training on UDL or the specific principles of MME. Their strategies were developed through a trial-and-error approach, based on personal experience rather than structured pedagogical frameworks.

I only learned about UDL or Multiple Means of Engagement through this study. Until now, I've just relied on my experience. I've taught for over 20 years and have long supported students with disabilities. I keep what works and let go of what doesn't.
—Willow, School B

This finding supports those of (Han and Lei, 2024; Lambert *et al.*, 2023), who noted that teachers in developing countries often have limited access to UDL literature and related professional development opportunities.

3.5.1.2. Resource constraints

Many teachers reported that limited access to instructional materials, adaptive technology, and time made it difficult to differentiate instruction effectively.

Sometimes I want to give more task options, but many students aren't used to that, or they don't have access to laptops. And I don't have enough time to explain everything in detail.
—Rose, School G

Basham *et al.* (2020) emphasize that effective UDL implementation is closely linked to having adequate infrastructure and sufficient planning time, which enables teachers to design meaningful and inclusive experiences.

3.5.1.3. Institutional resistance and administrative burden

Some teachers reported that the curriculum structure and administrative demands made it challenging to innovate in their classrooms.

When your teaching looks too different from everyone else's, it sometimes draws attention. So, I tend to play it safe, even when I know some students need something different.

—Miles, School D

Forget learning about UDL. I'm already overwhelmed by administrative tasks. With this new curriculum, I must dedicate time to learning it, and I have more teaching documents to prepare than before. I just don't have much time left to design lessons that truly fit each student's needs.

—Nancy, School H

These findings align with (Rao *et al.*, 2021), who found that rigid bureaucracies and a lack of space for professional experimentation often hinder UDL-based pedagogical innovation.

3.5.2. Teachers' reflections on the implementation process

Despite these challenges, many teachers shared thoughtful reflections on the need to engage students through more flexible and empathetic approaches.

I've realized that students with disabilities need special attention—not in a condescending way, but in a supportive one. We need to help them find their own ways of learning. And I'm still learning how to become the kind of teacher who can accommodate that.

—Diana, School J

From experience, I've learned that students are more motivated when given choices, and when they feel heard. That boosts their confidence.

—Melanie, School C

This school has long been a choice for blind students. They often don't think of themselves as disabled—and neither do their classmates. Although we haven't fully implemented inclusive practices yet, even with a disability support unit, I can say that our teachers are disability-aware. Our principal always reminds us to 'teach with heart.'

—Kyle, School F

These reflections point to a growing pedagogical awareness among teachers. Engagement is no longer viewed merely as physical presence or task completion, but is being redefined as a meaningful, emotional, cognitive, and social relationship with learning (Slaten *et al.*, 2016; Wang and Degol, 2016).

From a theoretical standpoint, the challenges teachers face highlights a gap between the transformative ideals of UDL and the structural realities of classroom teaching. On the one hand, teachers demonstrate competency, creativity, and care in responding to the diverse needs of their students. On the other hand, systemic limitations restrict their capacity to implement these ideas consistently. This gap mirrors the findings of Fränkel *et al.* (2023), who reported that science teachers often feel “caught” between their aspirations for inclusive practice and the constraints of standardized curricula and outcome expectations. In the Indonesian context, where the transition to *Kurikulum Merdeka* is still unfolding, this study underscores the importance of integrating UDL training into practice-based teacher education and reflective learning programs (Efendi *et al.*, 2022).

4. Theoretical and practical implications

4.1. Theoretical implications

This study makes a significant contribution to the development of the UDL framework, particularly in the implementation of the MME principle in chemistry education within developing country contexts. The findings reveal that although most teachers were not formally introduced to UDL, many of them intuitively applied strategies aligned with engagement principles, drawing from personal experience, local knowledge, and contextual understanding. These intuitive practices are important for the advancement of UDL theory because they demonstrate how engagement strategies can emerge organically in diverse educational settings, independent of formal training or Western-centric pedagogical discourse. By capturing these grassroots practices, the study highlights how UDL can be enriched through context-sensitive adaptations that reflect cultural relevance, resource constraints, and lived classroom realities. Such evidence not only validates the universality of UDL principles but also expands the theoretical framework by integrating locally grounded innovations that make inclusion more practical and sustainable in developing country contexts.

Moreover, these results reinforce the idea that UDL offers flexibility for adaptation within diverse cultural and social frameworks (Rao and Meo, 2016). Specifically, the teacher practices identified in this study, such as offering choice, contextualizing content, and encouraging student reflection, introduce new contextual dimensions to interpreting *recruiting interest*, *sustaining effort*, and *self-regulation*. Moreover, this study extends the UDL literature by highlighting the critical role of teacher agency as a mediating factor between theory and practice.

Furthermore, the findings challenge the assumption of universality embedded in many global pedagogical models. In Indonesia, issues such as administrative workload, structural resistance, and limited professional development opportunities suggest that the implementation of UDL is significantly influenced by the interaction between theory and local realities. Accordingly, this study supports the call for designing UDL implementation models that are more decentralized and situated, tailored to the unique social, political, and educational characteristics of local contexts, rather than adopting standardized, Global North-based frameworks.

4.2. Practical implications for education and policy

4.2.1. For teachers and education practitioners

The study finds that many teachers have independently developed strategies aligned with MME, even without explicitly referencing the UDL framework. Therefore, future teacher training programs should emphasize strengthening conceptual understanding of UDL, with a focus on the engagement principle; translating UDL principles into instructional design that reflects local classroom realities; and fostering collaborative reflection among teachers to document and disseminate effective practices. Training content should not merely introduce UDL as a theoretical construct, but also guide teachers in explicitly linking their day-to-day practices with MME principles (Rao *et al.*, 2021).

4.2.2. For schools and educational institutions

Schools must create supportive systems that enable teachers to access time and space to design flexible learning

experiences, apply formative assessments and differentiated learning goals, especially for students with SEND, and actively involve students in designing tasks and making classroom decisions. These practices can be gradually institutionalized through lesson study programs, reflective supervision, and professional learning communities (such as MGMP or KKG) focusing on inclusive pedagogy.

4.2.3. For policymakers

The findings of this research emphasize the need for integrating UDL principles into national curriculum frameworks, teacher supervision guidelines, and educator performance evaluations; providing financial support and affirmative policies for developing adaptive learning platforms and instructional tools; as well as teachers should adopt training models that are not solely technical in focus but also grounded in theoretical understanding and values of social inclusion. The implementation of *Kurikulum Merdeka* in Indonesia offers a promising opportunity to integrate UDL due to its inherent flexibility and emphasis on differentiated learning. However, this potential will remain unrealized unless it is accompanied by derivative policies that explicitly promote inclusive education grounded in universal design principles.

5. Conclusions

This study investigated how secondary school chemistry teachers apply the Multiple Means of Engagement (MME) principle from the Universal Design for Learning (UDL) framework to promote both engagement and a sense of belonging among students with Special Educational Needs and Disabilities (SEND) in chemistry classrooms. The findings reveal that while teachers often intuitively apply strategies that align with MME, such as providing learning choices, contextualizing lessons, offering constructive feedback, and facilitating reflection, these practices are not yet consistently guided by a formal pedagogical understanding of UDL. Teachers' efforts to recruit student interest, sustain effort, and support self-regulation have shown promising effects in increasing students' emotional involvement, classroom participation, and social connection, key indicators of engagement and a sense of belonging. However, the absence of differentiated learning goals, limited access to training, and structural barriers constrain the full realization of inclusive learning environments.

Theoretically, this study expands the UDL literature by offering grounded evidence from a Global South context. It highlights the crucial role of teacher agency in translating global pedagogical ideals into practical, local applications. Practically, it highlights the need for UDL-based professional development that supports teachers in intentionally designing learning experiences that promote engagement and nurture students' sense of inclusion and identity within the classroom community. By centering student engagement and belonging as core instructional design goals, this study argues that inclusive education, particularly in chemistry, can move from aspiration to realization through thoughtful, equitable, and contextually responsive pedagogical practice. While this study offers valuable insights into how teachers perceive and implement strategies to foster student engagement and belonging, it does not include the voices or perspectives of the students themselves. Future research could triangulate these findings by exploring how students, particularly those with disabilities, experience and interpret these engagement practices in real-time learning contexts.

Authors' contribution

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Conflict of interest

The authors declare that there is no conflict of interest.

Data availability statement

The data will be available upon request.

Artificial Intelligence usage statement

The authors declaration of Generative AI and AI-assisted technologies in the writing process: during the preparation of this work, the author(s) used [ChatGPT 4o] for translating, editing, and final review of writing. After using this tool/service, the author(s) reviewed and edited the content as needed and are fully responsible for the publication content.

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