Designing an inclusive chemistry learning environment for intellectual disabilities through Universal Design for Learning (UDL) in periodic properties elements

Hana Salsabila Virani[1], Teguh Bedjo Santoso[2], Rahmania Fitrah Sari[1], Findiyani Ernawati Asih[1], Dian Novita[1]*

[1]Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Ketintang Street No.1, Surabaya, East Java, 60231, Indonesia

[2]Department of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Ketintang Street No.1, Surabaya, East Java, 60231, Indonesia

*Corresponding author, email: diannovita@unesa.ac.id

Article History

Received: 15 November 2025

Revised: 20 January 2026

Accepted: 9 February 2026

Published: 1 March 2026

Keywords

Conceptual understanding

Intellectual disability

Inclusive learning environments

Periodic properties of elements

Universal Design for Learning (UDL)

Abstract

Inclusive education is a learning approach that accommodate the diverse abilities of students, including students with intellectual disabilities. However, implementation in chemistry learning which has abstract concepts, presents challenges for students with intellectual disabilities. Conventional chemistry learning tends to be limited to fulfilling cognitive needs. This research aims to examine the implementation Universal Design for Learning (UDL) principles in building an inclusive learning environment and support conceptual understanding of periodic properties This research employed a mixed-method embedded design, with qualitative data serving as the primary data and quantitative data supporting it. The subjects were three eleventh-grade students with intellectual disabilities at Senior High School 10 Surabaya. Qualitative data were gathered by means of observation, interviews, and video documentation, that processed using NVivo 11 software, quantitative data were obtained through pretests and posttests, analyzed use N-gain values. The results from this research demonstrate that implementation of UDL through the principles of representation, engagement, and action and expression was able to build an inclusive learning environment by providing flexible learning access and tailored to students' needs. In addition, the results of N-gain analysis reveal an improvement in conceptual understanding with a high category (average N-gain = 0.93). These findings confirm highlight that the application of UDL as an approach to more inclusive in chemistry learning environments for students with intellectual disabilities.

How to cite: Virani, H. S., Santoso, T. B., Sari, R. F., Asih, F. E., & Novita, D. (2026). Designing an inclusive chemistry learning environment for intellectual disabilities through Universal Design for Learning (UDL) in periodic properties elements. *Journal of Environment and Sustainability Education, 4*(1). 144–159. doi: 10.62672/joease.v4i1.198

1. Introduction

Education has an important role in supporting children's academic and social development. Through education, children can socialize and learn new things to enhance their adaptive and cognitive abilities (Kumar, 2025). One type of education that can provide equal learning opportunities for all students is inclusive education (Febriana, 2022). An inclusive learning environment plays an important role in providing equal opportunities for all students, especially students with intellectual disabilities (Hikmat, 2022). However, students with intellectual disabilities often have difficulty interpreting and understanding material that requires a high level of conceptual understanding, because teaching methods are not fully adapted to their needs (Devita et al., 2025).

Students with intellectual disabillities have limitations in cognitive, motor, and psychomotor development, which causes difficulties in adapting to new demands in the learning environment and social life (Szilagyi & Albulescu, 2023). Students with intellectual disabilities have some difficulty, especially in terms of adaptability, information processing, working memory, and understanding abstract concepts (Domenico et al., 2023). The limitations in accepting abstract concepts, such as those in science, make it difficult for students with intellectual disabilities to build representations of concepts (Maryanti, 2021). Meanwhile, low working memory leads to a lack of attention to receive and process the information presented (Saragih et al., 2024). This condition presents a challenge for students with intellectual disabilities, demanding a more adaptable and responsive learning approach, one of which is in chemistry learning, which requires high level conceptual understanding.

One of the topics in chemistry that demands a high level of conceptual understanding is the periodic properties of elements. In this case, students must be able to understand periodic trends and the relationship

doi: 10.62672/joease.v4i1.198

ISSN: 3025-0714

between properties (Febriyani & Mayasari., 2025). Students with intellectual disabilities increasingly face complex challenges in learning chemistry concepts related to periodic properties due to their limited abilities. Periodic properties of elements is a topic that studies patterns, interprets trends, and relationships between atomic structures through periodic properties (Priliyanti et al., 2021). In studying material on the periodic properties of elements, high levels of reasoning and mastery of related concepts are required to explain the relationship between atomic structure, electron configuration, and the periodic properties of elements (Ramadhan & Nisa, 2020).

Previous studies have similarly stated that students with intellectual disabilities have significant difficulties in learning chemical concepts that require high-level reasoning and conceptual integration, particularly on the topic of periodic properties of elements (Abels et al., 2020). The difficulties experienced by students with intellectual disabilities in learning chemical concepts are often caused by teaching methods that are not optimal in providing cognitive support (King sears & Johnson, 2020). Similar conditions observed in the field, based on interviews on 8 August 2025 conducted with chemistry teachers and special teachers assisting students with intellectual disabilities at senior high school 10 Surabaya, revealed that chemistry learning is still not optimal for students with intellectual disabilities in grade XI. Chemistry teachers also revealed that students with intellectual disabilities in grade XI often experience difficulties in understanding chemistry material that requires a high level of conceptual understanding. This indicates that the fulfillment of chemistry learning standards for students with special needs has not yet been fully realized. Interviews also revealed that learning activities are still largely conducted through conventional teaching methods, such as discourse, and there is no learning media designed to facilitate conceptual understanding for students with intellectual disability, so there is no method systematically considered to involving of cognitive processes and express conceptual understanding. As a result, the learning environment does not fully support meaningful participation and conceptual understanding for students with intellectual disabilities. Conceptually, intellectual disability refers to significant limitations in intellectual functioning, including reasoning, problem solving, and learning abilities, as well as limitations in adaptive behavior covering social, conceptual, and practical skills, which manifest during the developmental period.

Based on these findings in the field, the solution to this challenge is to give a more inclusive approach to chemistry learning through the implementation of Universal Design for Learning (UDL). Universal Design for Learning is a teaching system developed to fulfil diverse learning requirements and abilities of all learners (Rosmi & Jauhari., 2022). The main purpose of UDL design is to eliminate obstacles and create a supportive learning environment where every student can succeed (Priyadharsini & Mary, 2024). Learning through the implementation of UDL can also create ways to help everyone, regardless of their circumstances, to assist in the learning process (Lee et al., 2017). Especially in chemistry learning, UDL is able to create more inclusive chemistry learning in order to achieve learning objectives, as well as teaching materials (Wulayalin et al., 2024). In implementing universal design for learning (UDL) there are three key principles, representation, engagement, action and expression (Lee et al., 2017). The principle of representation is through presenting information to fulfil the needs of students, including the use of text formats, visuals, and other strategies to make the content presented easy for students with intellectual disabilities to understand (Priyadharsini & Mary, 2024). Engagement, to grow students' motivation in learning by combining their interests (Lee et al., 2017). Action and expression gives students the opportunity to choose the form of assessment and how to display evidence of achieving learning objectives that align with their abilities (Bracken & Novak., 2019).

In the context of chemistry learning, the principles of universal design for learning (UDL) become relevant with the support of representations, such as those presented in visual forms in the material on the periodic properties of elements. Representations of the periodic properties of elements, such as animations and interactive simulations, can facilitate students' understanding of the content (Priyadharsini & Mary, 2024). Meanwhile, the principle of engagement provides flexible activities to foster motivation in the learning process. Furthermore, action and expression principle enables students to demonstrate conceptual understanding (Arduini, 2020). This principle is implemented by answering interactive simulations either through verbal explanations or visual representations according to the interests of intellectual disabilities students.

Based on the description above, implementation of universal design for learning (UDL) in chemistry learning, especially in the material periodic properties of elements, is able to create an inclusive learning environment and improve the understanding of learning concepts through the abilities and needs of intellectual disabilities student. Meanwhile, several studies that specifically examine the implementation of principles of universal design for learning (UDL) in chemistry learning to create an inclusive environment and how it contributes to the understanding of concepts of students with intellectual disabilities are still limited. Most previous studies have focused on general principles without delving deeply into the application mechanisms of each UDL principle to chemistry topics that require a high level of conceptual understanding. Therefore, this is a gap highlights that need for research deeply systematically examines the implementation of Universal Design for Learning principles in chemistry instruction to build an inclusive learning environment, particularly for intellectual disabilities students. Based on this explanation, this research focuses on formulating the main problems: 1) How are the principles of Universal Design for Learning (UDL) implemented in building an inclusive learning environment for intellectual disability students in the topic of periodic properties of elements. And also, 2) How does the application of UDL contribute to improving intellectual disability students' conceptual understanding.

2. Method

The research method used a embedded mixed-method design, namely one data type (quantitative or qualitative) is embedded within a larger study of the other type by using one phase of data collection, where quantitative and qualitative data are collected simultaneously (Creswell, 2009). Mixed-method research is research that utilizes both quantitative and qualitative approaches throughout the research process (Agus Suradika, 2019). In this research, qualitative data served as the primary strand, while quantitative data were embedded as a complementary strand to support and strengthen the qualitative findings. The analysis data framework will be explained in Figure 1.

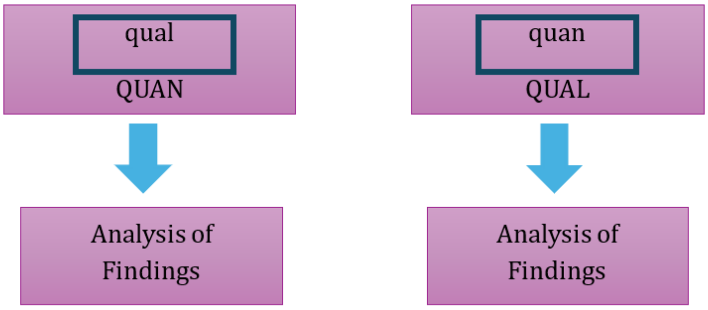


Figure 1. Embedded Mixed-Method Design Flowchart (Creswell, 2009)

Based on Figure 1 the quantitative component (QUAN) constitutes the main strand of the research and focuses on measuring students' conceptual understanding of periodic properties. The qualitative component (qual) is embedded within the quantitative phase to explore students' learning experiences, cognitive processes, and responses to the UDL-based learning environment. Qualitative data were collected through interviews, observations, and documentation, which was analyzed using NVivo 11 software. This integration allows the qualitative data to connect with qualitative and quantitative data.

Meanwhile, the quantitative data in this study serve as complementary data to strengthen the first finding in confirming the impact of UDL implementation on students with intellectual disabilities in improving conceptual understanding through pretests and posttests use N-gain analyzed to calculate the level of enhancement in conceptual understanding. With this combination, it is possible to obtain a strong integration between the picture of the learning process taking place in the classroom with numerical evidence of improved learning outcomes. The research procedure is explained in Figure 2 below.

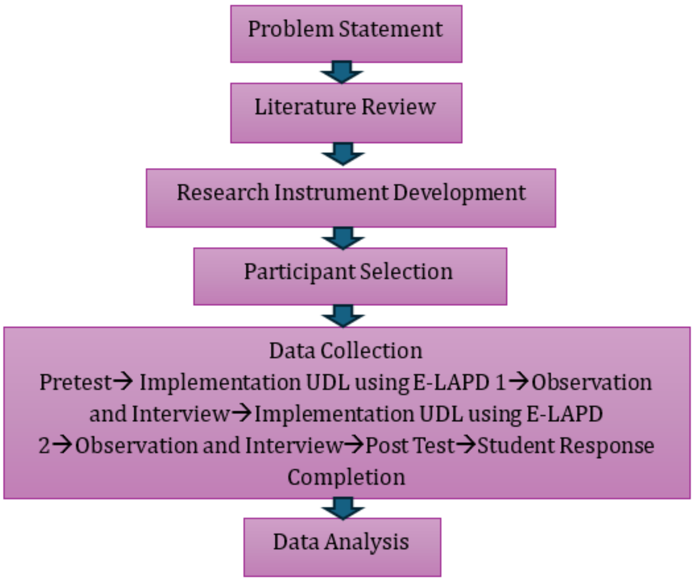


Figure 2. Reserach Flowchart

This research was held on August 8, 2025, at senior high school 10 Surabaya, using chemistry material periodic properties of elements. Research procedures begin with problem formulation related to the challenges faced by students with intellectual disabilities in understanding abstract chemistry concepts, followed by a literature review to obtain a theoretical basis to establish the theoretical foundation of inclusive chemistry learning and Universal Design for Learning (UDL). Instruments consisting of observation sheets to observe the entire learning process, interview guidelines to explore students' learning experiences, understanding of material and difficulties. Pretest and posttest instruments was created to measure students initial and final conceptual understanding of the periodic properties of the elements, and student response questionnaires responses to examine the learning environment using UDL (Universal Design for Learning), including E-LAPD worksheets as a learning media designed to operationalize UDL principles. In this research, the E-LAPD media was divided into two subtopics of the material on the periodic properties of elements, first media about atomic radius, and ionization energy, then second media is electron affinity and electronegativity. E-LAPD was created using Canva and Liveworksheet software with features such as join, drag and drop, select, and open answers.

The data collection process first consists of a pretest. The pre-test was conducted to determine students' initial understanding. During the taking process, there were only interruptions related to the pre-test, such as the length of time it took to complete the pre-test questions. Then followed by the implementation of chemistry learning through UDL use first with material atomic radius, and ionization energy, then interviews, followed by the implementation of UDL on the secondly with material subtopics electron affinity and electronegativity, then interviews with observers were conducted with students to gain insights into their understanding and learning experiences and posttests, then finally filling out the student response questionnaire.

Research subjects: The subjects consisted of three students with intellectual disabilities in grade XI at senior high school 10 Surabaya who were determined through recommendations from guidance counselors and the results of academic assessments conducted by the school. Three subjects in this study had IQ (Intelligence Quotient) scores above the general threshold for identifying intellectual disabilities. However, the school classified the three students as having intellectual difficulties according to the assessment criteria applied by the school when admitting students with special needs, which is characterized by limitations in cognitive functions, such as adaptation, conceptual, reasoning, and working memory. This provision is in line with the guidelines of the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5), which states that the determination of the diagnosis of intellectual disability is not only based on IQ (Intelligence Quotient) scores, but also considers real limitations in adaptive, social, and conceptual functions (APA, 2013). Thus, this study refers to the results of the school's assessment criteria and policies to assess the condition of students comprehensively, not only based on IQ scores. The limited number of participants in this study was due to the limited annual quota for special needs students at the school, which is 5% of the school's quota.

The students' identities are presented in Table 1. Students were selected through purposive sampling techniques based on the following characteristics: (1) students showed weaknesses in processing abstract information, (2) difficulties in maintaining focus or attention, and (3) requiring further learning adaptations. Meanwhile, guidance counselors, special assistance teachers, and chemistry teachers served as supporting informants for triangulation information related to the students' learning development. The term intellectual disability as borderline intellectual function (BIF), or also known as borderline mental retardation, is a child who is slow to learn, characterized by the function of requiring more need a time and greater in the process of acquiring knowledge than their same age peers (Cheon, 2024). Generally, student intellectual disability have an IQ (Intelligence Quotient) score between 70 and 90, slightly below normal children (score 100) and above mentally retarded children (score <70) (Nurfadhillah et al., 2021). Additionally, they often exhibit hyperactivity and attention deficit disorder, which makes them more focused on physical activity than on the teacher (Patel et al., 2020).

Table 1. Research subject

No.	Name of Student	Age	IQ	Gender
1.	DADH	17	108	M
2.	AHA	18	104	M
3.	E	18	87	F

The characteristics of each student with intellectual disabilities are shown in Table 2 below.

Table 2. Charactheristic Research Subject

No.	Name of Student	Characteristics
1.	DADH	DADH is an intellectual disability that has a condition that describes a specific learning disability in students, rooted in a neurological disorder related to language processing. This affects to his ability to engage in academic activities and social activities. DADH's IQ score is 108, which is still in the average category. DADH also has ADHD, which makes it difficult to regulate emotions and has difficulty taking direction. DADH has difficulty maintaining attention on one task and is easily distracted. Therefore, strict rules are needed regarding

No.	Name of Student	Characteristics
		acceptable and unacceptable behavior. Furthermore, they are usually uncomfortable in crowds and prefer to be alone.
2.	AHA	AHA students have an IQ score of 104, which is considered average, so their thinking skills are within normal limits. These students tend to be sociable and adapt well to their social environment. However, in academic settings, AHA often feels discouraged and reluctant to do anything. Thus, AHAs are not yet able to maximize their potential. Therefore, AHA students require consistent guidance and support from more experienced individuals.
3.	E	Student E has an IQ score of 87, which is in the lower average category. Her ability to think, comprehend, and concentrate is at a fairly good enough. However, Student E tends to lack self-confidence and is easily influenced by moods, so it takes longer to adjust. Student E also has a reading disability; compared to students her age, E has lower reading ability.

Research instrument: Data were collected through (1) E-LAPD as a learning media containing exploration activities, concept applications, and learning conclusions made through Live Worksheet digital media integrated with the UDL (Universal Design for Learning) model by emphasizing three main principles, representation, engagement, and action & expression, In the principle of representation by presenting brief material can be presented through video, text or images. Meanwhile, engagement is used to increase student motivation by presenting images of phenomena in everyday life. Meanwhile, the principle of action and expression is to involve students. This can be done by providing a concluding expression regarding the material that has been presented. (2) observation sheets, to record learning behavior during data collection, student responses, and interactions with the learning environment through observers for each student, (3) interview sheets, to explore student experiences related to learning interests, access and support for inclusive learning environments. Interview sheets were used to explore students' learning experiences, including their learning interests, accessibility of instructional materials, and perceived support within the inclusive learning environment. The interviews included questions such as students' preferences toward visual or interactive learning media, difficulties encountered when understanding periodic properties of elements, and their perceptions of how UDL-based activities supported their participation and understanding during learning. (4) pretest and posttest sheets to measure conceptual understanding before and after learning consisting of multiple choice questions at the cognitive level C2 (understanding), C3 (application) and C4 (analyze) according to student abilities. C2-level questions required students to identify periodic trends such as determining the relative atomic radius of selected elements, C3-level questions required students to apply periodic trends to predict element properties, and C4-level questions required students to analyze relationships between atomic structure and periodic properties. And (5) student response questionnaires to strengthen qualitative findings regarding student perceptions of the learning environment through UDL.

Qualitative data analysis techniques for implementing UDL in inclusive learning environments and learning experiences: Data were analyzed using Nvivo 11 software by dividing it into several stages. The first stage, open coding through the results of interview transcripts, observation notes, to form the main nodes based on the principles of UDL, namely representation containing visual support, engagement containing motivation or attention, and action & expression containing verbal explanations. The second stage of cluster analysis was used to see the similarities in student learning patterns built through UDL from the results of student interviews. Thus, through this process the correlation value between student responses can be identified through the level of similarity of cognitive activities during the implementation of UDL in an inclusive learning environment. And the third stage, through matrix coding queries to connect between the principles of UDL and aspects of the inclusive learning environment, student interactions with learning media, and each individual's response.

Quantitavite data for conceptual understanding analysis technique for students with intellectual disabilities: Data were gathered using N-gain scores from pretest and posttest results to determine improvements in students' conceptual understanding (Equation 1). The N-gain results were then clarified using N-gain score criteria. The N-gain score criteria are presented in Table 3.

$$g = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score} \quad (1)$$

Table 3. Criteria of N-gain Score

N-gain Score	Criteria Score
G ≥ 0.7	High
0.3 ≤ G < 0.7	Moderate
G < 0.3	Low

(Hake, 1998)

3. Results and Discussion

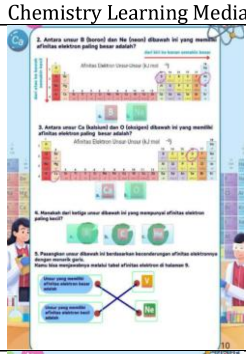
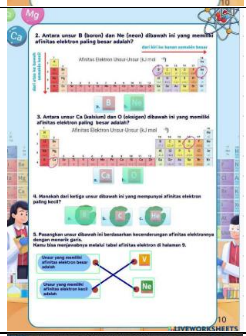
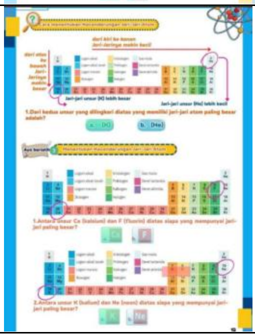
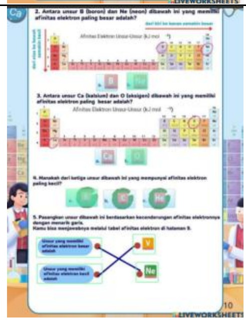
3.1. Implementing UDL to Building an Inclusive Learning Environtment

The learning design used in this research is Universal Design for Learning (UDL) includes principle to create an inclusive learning environment for overall learning, and also help reduce learning difficulties to improve conceptual understanding of the material. The UDL learning design principles used in this study to create an inclusive learning environment for students with intellectual disabilities include different ways of representation, engagement, action and expression principles as follows.

3.1.1. Representation

The learning media provided to students with intellectual disabilities use the UDL approach, namely representation. Under this principle, students are presented with material on the periodic properties of elements through images, videos, and summaries that are easily understood by students with intellectual disabilities, after the presented of the material, students are given practice questions designed using illustrations and a presentation method that is easy to understand. The results of applying the representation principle are explained in the Table 4 below.

Table 4. Results of Implementing UDL Representation Principles

Name	Chemistry Learning Media 1	Chemistry Learning Media 2
DADH		
AHA		
E		

Based on the results of the learning media using UDL on the representation principle, students with intellectual disabilities were able to apply it. This was indicated by the students' ability to answer the practice questions given in the learning media using the representation principle regarding the periodic properties of elements. In the practice questions, students were asked to determine elements according to their periodic properties. Based on the required interviews, students expressed that the statements and presentations were easy to understand, so they were able to answer them correctly and understand the material. This was proven by cluster analysis by connecting the similarities found in the interview results to produce the same matrix. The analysis resulted in a relationship between the interview results and the implementation of the UDL representation principle in the three students with intellectual disabilities, with a Pearson coefficient value ranging from 0.67 to 0.83. Table 5 shown a coeficient corellation pearson result for chemistry learning media 1 and 2 with UDL representation.

Table 5. Coeficient Corellation Pearson Result for Chemistry Learning Media 1 and 2 with UDL Representation

(Learning Media 1)		
Node A	Node B	Pearson Correlation
DADH	AHA	0.831859
E	DADH	0.787659
E	AHA	0.672602
(Learning Media 2)		
Node A	Node B	Pearson Correlation
DADH	AHA	0.831859
E	DADH	0.787659
E	AHA	0.672602

Based on the results of the correlation value of three students with intellectual disabilities in learning media 1 showed the results of 0.67; 0.78; 0.83. DADH students and AHA students have a correlation value of 0.83, and E students and DADH students have a correlation of 0.78, while E students and AHA students have a correlation of 0.67. Then for learning using media 2, the third student showed the same correlation results as learning media 1. The third student had a different interview answer pattern, but the existence of a different answer pattern was the answer expected by the researcher. The principle of representation in chemistry learning media 1 shows how easy it is in the implementation process. This is supported by the results of the analysis matrix coding query that the three students with intellectual disabilities showed involvement in the visual understanding aspect. In Figure 3, it can be seen that the difference in frequency is relatively small, this shows that the three students with intellectual disabilities benefited from the representation principle designed through the implementation of UDL.

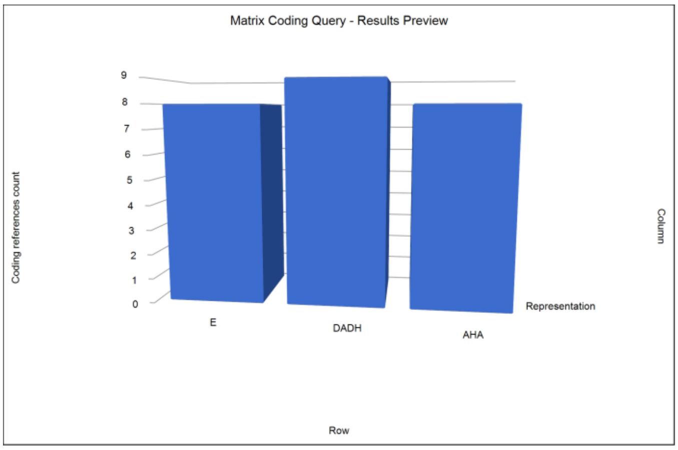


Figure 3. Diagram of Student for Representation

Based on the findings obtained from the Nvivo 11 data processing through the query coding matrix to analyze the implementation of UDL in building an inclusive environment, it shows that the principle of UDL representation, in the three AHA students appeared with a high frequency and was relatively balanced. AHA students with a frequency of (8) tended to be involved in visual representation but did not reach DADH students. In the interview, AHA said that "*saya mudah memahami karena ada gambar yang berwarna dan menarik.*" Students who prefer visual forms tend to remember information more easily through images, animations, or similar visual media. This aligns with previous research that suggests visual representation can increase student motivation, learning experience, and engagement during learning process (Zahran et al., 2025). Relate the results to dual coding theory, cognitive load theory, and learner variability in UDL.

In student E, the frequency (8) shows that representation in the implementation of UDL also plays a role. In observations, student E tends to have difficulty reading long sentences, so it would be better to provide explanations in the form of videos or animations. The addition of images and videos in learning for students with intellectual disabilities makes them prefer learning activities (Connor et al., 2018). Meanwhile, in the interview, student E said that "*lebih paham materinya dengan gambar, dan video. jadi nggak bosan.*"

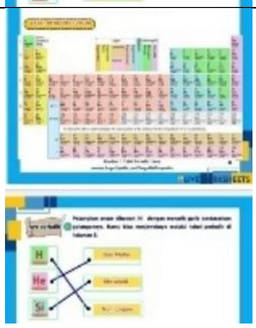
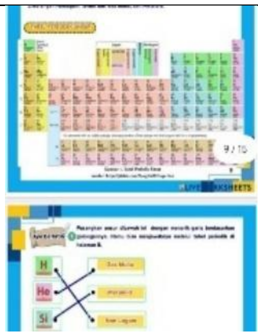
Evidence: "Student E understands the material slowly and needs to be repeated aloud." (observer 3, August 8, 2025).

Meanwhile, the DADH students with the highest frequency (9) indicated that visual representations dominated their efforts in building an inclusive learning environment. In interviews and observations, DADH showed that DADH was able to locate elements in the periodic table by color. This was also shown in the interview, where DADH stated that "*tidak bosan, karena ada gambar-gambar dan warna*." Learning by presenting visual forms can help students in the learning process and can increase motivation (Adi et al., 2023). For students with intellectual disabilities, who often experience limitations in verbal processing and working memory, visual elements such as color-coded periodic tables, diagrams, and animations help strengthen conceptual understanding by reinforcing verbal information with concrete visual cues. According to Dual Coding Theory, learning is enhanced when information is presented through both verbal and visual channels, allowing learners to build multiple mental representations of the same concept. This indicates that UDL can build an inclusive environment by providing alternative representations for processing information.

3.1.2. Engagement

In the principle of UDL (Universal Design for Learning) engagement is presented in the chemistry learning media in this study to create student interest and motivation to learn. In this research learning media presents interest and motivation by presenting activities to recall previously presented material, in order to connect previous understanding. Also, students are given everyday phenomena to be able to foster motivation in learning. In this principle, it is presented by providing the phenomenon of salt to help motivate them in learning the periodic properties of elements, images of salt are used to recall previous material and provide an illustration if salt contains elements in it, namely Na and Cl. As well as images of the periodic table of elements that there are many elements in nature that have different periodic properties and tendencies. The presentation of material in this research learning media uses text, images or videos designed with the aim of helping motivate and understand the material easily according to students' abilities. In interviews that have been conducted, providing images of elements in salt helps motivate them to learn the periodic properties of elements. The following are images that are able to motivate students with intellectual disabilities. Results of implementing udl representation principles can be seen in Table 6.

Table 6. Results of Implementing UDL Representation Principles

Name	Chemistry Learning Media 1	Chemistry Learning Media 2
DADH		
AHA		
E		

Based on the results of the learning media work using UDL (Universal Design for Learning) engagement principles, students with intellectual disabilities were able to apply them. Through the presentation of images of salt and the periodic table of elements, students were able to remember the material that had been taught previously and were motivated to learn the material on the periodic properties of elements. The engagement principle was then analyzed using cluster analysis to group similarities in the interview transcripts. Based on the results of the interviews, students revealed that they felt motivated by the images or illustrations provided in the engagement principles in the learning media on the periodic properties of elements. Cluster analysis through interview results from chemistry learning media 1 and 2 showed Pearson correlation values ranging from 0.67-0.84. The Table 7 of Pearson correlation values based on the results of the engagement principle interviews is as follows:

Table 7. Coeficient Corellation Pearson Result for Chemistry Learning Media 1 and 2 with UDL Engagement

(Learning Media 1)		
Node A	Node B	Pearson Correlation
DADH	AHA	0.831859
E	DADH	0.787659
E	AHA	0.672602
(Learning Media 2)		
Node A	Node B	Pearson Correlation
DADH	AHA	0.842543
E	DADH	0.770801
E	AHA	0.733689

Based on the results of learning media that use the second principle of UDL, namely engagement, students with intellectual disabilities showed similar results as evidenced by the results of interviews. This is shown by the interviews of students who are motivated in learning the periodic properties of elements and are able to recall previous material. This is proven by cluster analysis by connecting the similarities found in the interview results to produce the same matrix. The analysis produced a relationship between the interview results and the application of the UDL engagement principle in three students with intellectual disabilities, with Pearson coefficient values ranging from 0.67 to 0.84. In learning media 1 showed the results of 0.67; 0.78; 0.83. Then of learning media 2 showed the result 0.84; 0.77; 0.73. The principle of engagement shows that students can be motivated by learning media through images of salt and the periodic table of elements and allows them to remember the material that has been presented, namely atomic structure.

Based on the results of the query coding matrix analysis on Figure 4, the UDL engagement principle, it can be seen that the three students demonstrated involvement in building an inclusive learning environment. This illustrates the difference in motivational needs for learning.

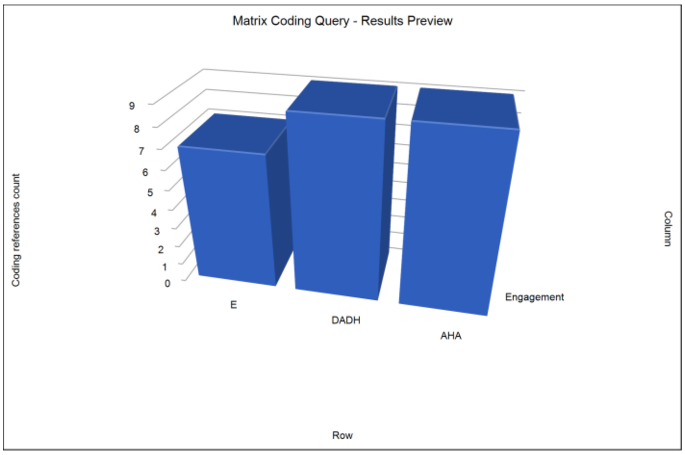


Figure 4. Diagram of Student for Engagement

DADH students with high engagement frequency are seen. In addition, the DADH engagement principle shows that the learning environment provides space for them to be able to work on activities comfortably. The engagement principle observed in DADH indicates that the learning environment provides opportunities for students to work on activities at their own pace. For example, during the E-LAPD learning activity, DADH students were allowed to complete drag-and-drop and matching tasks at their own pace while receiving step-by-step instructions and visual cues, such as a color-coded periodic table and directional. In observations, DADH students participated in learning and answered activities on E-LAPD with enthusiasm. However, obstacles in DADH often include quickly losing focus of attention, so in learning activities, instructions are used as guides and the provision of color or image manipulation to help maintain focus as well as verbal support. This illustrates that engagement in UDL is not only influenced by the material, but also how the learning environment can provide access that maintains student attention. This is supported by DADH interviews which stated that "*tidak bosan, senang ada warna-warnanya.*"

> Evidence: "DADH students are very enthusiastic in carrying out learning activities, but occasionally like to ask questions outside the topic which can distract students' attention in the learning process." (observer 2, August 8, 2025).

AHA students have the same frequency as DADH but have different characteristics. AHA demonstrates brief activities and provides feedback. In the E-LAPD activity, AHA demonstrates through focusing on remembering images of periodic property trends of elements and AHA reads visual materials more than once, which means AHA is able to demonstrate self-regulation actions. Also, in observations, AHA tends to be more comfortable and not afraid of making mistakes because there is room to try without pressure and support from observers. Therefore, AHA appears more confident.

> Evidence: "Students participated in the activities well, and occasionally read more than once to understand better." (observer 1, August 8, 2025).

Meanwhile, student E demonstrated a lower level of engagement (frequency score = 7) based on the performance assessment rubric used in this lesson. Engagement was evaluated using an observation rubric consisting of indicators such as active participation in learning tasks, completing activities, responsiveness to instructions, and confidence in interacting with learning materials. However, this frequency still indicates a positive impact of UDL implementation. Student E was able to learn gradually, although he required additional time to understand the material and exhibited shy behavior during learning activities. Student E required more verbal reinforcement and structured instruction at a slower pace. (7). However, this frequency still indicates a positive impact on UDL implementation. This is evidenced by the fact that student E is able to learn gradually, although she needs a little time to understand the material and is a bit shy. Student E requires more verbal reinforcement and structured, slow instructions. Students with intellectual disabilities require repetition to understand something (Browder et al., 2018). However, the presence of activity options such as filling in the periodic trends of elements, matching, and repeated practice enabled Student E to persist in learning activities longer and with greater confidence. This indicates that the principle of engagement in UDL can reduce attentional barriers that require higher levels of support, such as for Student E.

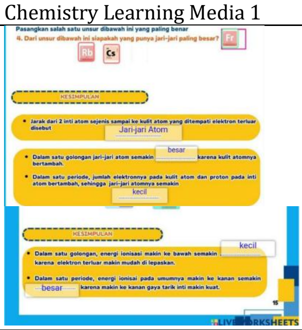
> Evidence: "Student E needs a gradual explanation and needs to be invited to make small talk so that he doesn't feel less confident in the learning process." (observer 3, August 8, 2025).

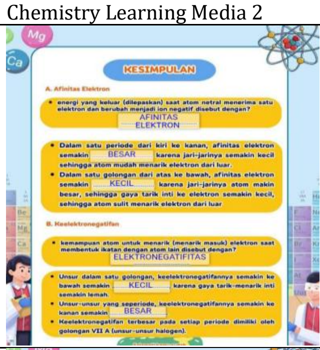
3.1.3. Action and Expression

The Universal Design for Learning (UDL) principles of action and expression were applied to chemistry learning media in this study to facilitate interaction and transmission of students' understanding of the material through coordinated conclusions regarding the material they have learned. This was provided to reinforce the concept of understanding the material after being given practice questions and materials. Students were instructed to fill in the conclusion column so they could interact and express their understanding of the material. The following is an illustration of the principles of UDL action and expression can be seen in Table 8.

Table 8. Coeficient Corellation Pearson Result for Chemistry Learning Media 1 and 2 with UDL Engagement

(Learning Media 1)

<table>
<tr><th>Name</th><th>Chemistry Learning Media 1</th><th>Chemistry Learning Media 2</th></tr>
<tr><td>DADH</td><td>
</td><td>
</td></tr>
</table>

Name	Chemistry Learning Media 1	Chemistry Learning Media 2
AHA		
E		

Based on the results of the learning media using UDL (Universal Design for Learning) principles of action and expression, students with intellectual disabilities are able to apply them. Through the presentation of the conclusion column on the material, students with intellectual abilities are able to answer it correctly. Based on the results of the interview, the use of practice questions and summaries of the material provided are able to provide students in answering conclusions related to the material on the periodic properties of elements. Answering conclusions after learning aims to determine whether students, especially students with intellectual abilities, can understand the material presented. Cluster analysis on the principles of action and expression through interview results from chemistry learning media 1 and 2 shows a Pearson correlation value ranging from 0.67-0.84. The Table 9 of Pearson correlation values based on the results of the engagement principle interview is as follows:

Table 9. Coeficient Corellation Pearson Result for Chemistry Learning Media 1 and 2 with UDL Engagement

(Learning Media 1)

Node A	Node B	Pearson Correlation
DADH	AHA	0.831859
E	DADH	0.787659
E	AHA	0.672602

(Learning Media 2)

Node A	Node B	Pearson Correlation
DADH	AHA	0.842543
E	DADH	0.770801
E	AHA	0.733689

Based on the results of the query coding matrix analysis on the UDL action and expression principles, it can be seen that the three students showed different abilities in expressing their understanding, Figure 5.

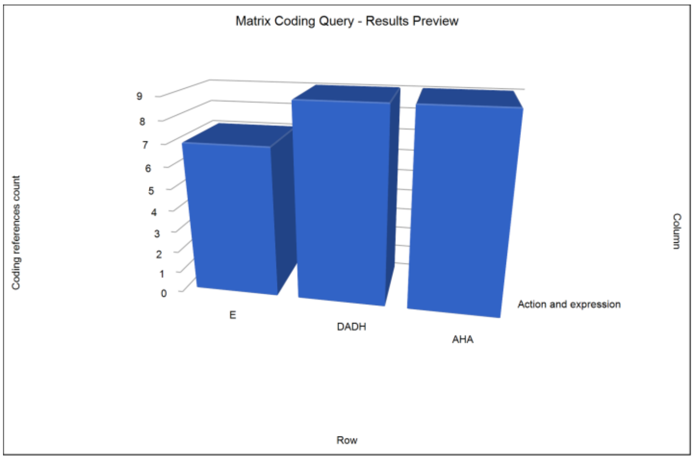


Figure 5. Diagram of Student for Action and Expression

Student E required additional scaffolding to organize her thinking. She tended to explain her answers verbally to the observer rather than writing them down, even though she needed validation from the observer. However, an inclusive learning environment through UDL, with opportunities for repetition and prior representation, helped Student E express her answers. For example, the observer had to first prompt by saying "*dalam tabel periodik energi ionisasi semakin ke bawah akan kecil, sehingga kalau ke kanan akan?*" So that student E is able to answer that "energi ionisasi ke kanan akan semakin besar."

Meanwhile, DADH students showed a high frequency (9) after implementing UDL. DADH students were able to demonstrate that an inclusive environment allows them to convey good answers verbally to observers. This is supported by DADH interviews which stated that "*elektronegativitas itu, kemampuan atom dalam menarik elektron.*" This illustrates that UDL in action and expression provides space for intellectual disabilities students to be able to express themselves widely.

> Evidence: "DADH students are able to explain the tendencies of periodic prop (observer 2, August 8, 2025).

AHA students were not only able to understand the material but also to express it through oral explanations during E-LAPD activities and interviews. This was demonstrated by AHA, who told observers that "*atom memiliki sifat unsur-unsurnya tersendiri seperti jari-jari atom dan energi ionisasi. Jari-jari atom jika semakin ke bawah makin besar dan juga semakin ke arah kanan kecil.*" This reinforces that action and expression can be a guide in demonstrating the understanding of students with intellectual disabilities.

> Evidence: "AHA students were helped by step-by-step instructions and color, so they could structure their arguments and explain them well." (observer 1, August 8, 2025).

This finding is directly able to answer the formulation of the first research problem by showing how the principles of UDL (Universal Design for Learning) are implemented to build an inclusive learning environment through representation, involvement, and actions and expressions of students with intellectual disabilities in chemistry learning.

3.2. The Impact of UDL on Intellectual Disability Student Conceptual Understanding

Based on quantitative analysis aimed at determining the conceptual understanding of intellectual disabilities students on the material of periodic properties of elements through the implementation of UDL, the analysis used pretest and posttest data. The pretest and posttest consisted of six multiple-choice questions designed to measure conceptual understanding at cognitive levels C2 (understanding), C3 (application), and C4 (analysis). In the level C2, students are asked to determine trends in atomic radius. At level C3, students can order trends in electron affinity from smallest to largest. Meanwhile, at level C4, students can analyze the reasons for trends in electron affinity. The data is presented in Figure 6.

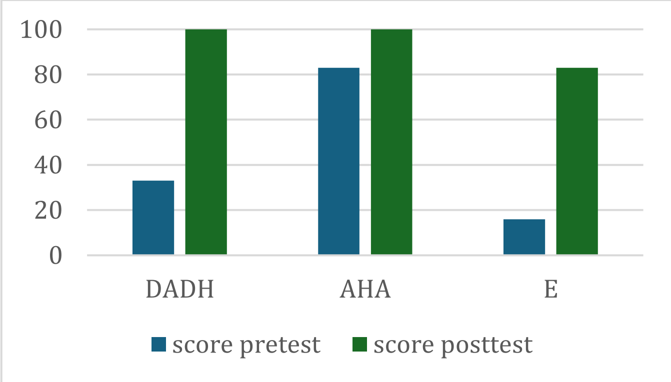


Figure 6. Pretest and Posttest Student Result

Based on the bar graph in Figure 6, there is an increase in scores for the three students with intellectual disabilities on the chemistry topic of periodic properties of elements, which consists of six multiple-choice questions. This increase in scores indicates that the implementation of UDL can effectively improve the conceptual understanding of intellectual disabilities students. Based on the results of quantitative data analysis, there was no decrease in scores in the post-test, this indicates that the implementation of UDL (Universal Design for Learning) in chemistry learning through chemistry learning media. To further reinforce the quantitative data findings, students pretest and posttest score were examined using N-gain analyzed. The result of the N-gain score are shown in Table 10.

Table 10. N-gain Score Result

Name of Student	Pretest score	Posttest score	N-gain
DADH	33	100	1.00
AHA	83	100	1.00
E	16	83	0.80
Average			0.93

Based on Table 10, the post-test scores of all students in this study sample increased, proving that the implementation of UDL through learning media on the periodic properties of elements was not able to build students' understanding of the material. This proves that the three students have a good conceptual understanding of the periodic properties of elements. Although the three students had high post-test scores, the post-test results still need to be explained in more detail. Students DADH and AHA obtained a perfect post-test score of 100, while student E obtained a post-test score of 83. This indicates that the post-test answers to the periodic properties of elements still contain errors. Student E incorrectly answered one post-test question, one of which was question number 5 which discussed the question of determining the tendency of ionization energy through atomic number.. Through further analysis, based on the observer's observations, this error was indicated because student E still had difficulty grasping the information contained in the question. Therefore, student E had difficulty in calculating, so student E had a little difficulty in answering question number 5 in the post, but through the application of UDL in chemistry learning, student E managed to improve his understanding of the material on the periodic properties of elements. This was indicated by an increase in the student's pretest score and posttest score.

Based on the results of the N-gain score from the pretest and posttest score on the periodic properties of elements material, the average score of the three students was $G \geq 0.7$, namely 0.93, which places the effectiveness of UDL which indicates a high level of learning improvement based on Hake's criteria (1998) classification. DADH and AHA students achieved an N-gain value of 1.00 that is indicated within the high category, indicating that the understanding of the DADH and AHA concepts increased. Meanwhile, student E got a score of 0.83 which is also still in the high category, this indicates that understanding of the concept has increased.

Based on the quantitative analysis above, it indicates that the implementation of UDL in chemistry learning on the topic of periodic properties of elements influences conceptual understanding by creating an inclusive learning environment. UDL creates an inclusive learning environment that allows each student to learn according to their own rhythm and learning style. This shows that the implementation of UDL in creating an inclusive learning environment is very important to help maximize opportunities for optimal conceptual understanding.

4. Conclusion

Based on the results obtained from this research that has been conducted, it can be inferred that the implementation of Universal Design for Learning (UDL) is able to create an inclusive and adaptive learning environment for intellectual disability in the material of periodic properties of elements. The provision of multiple means of representation, engagement, and action and expression, such as visual supports, varied interactive activities, and flexible response formats enabled students to access abstract chemical concepts in ways that aligned with their individual learning needs. By providing visual representations, providing varied activities such as matching and drawing lines and providing ways that allow for students to express their understanding of UDL can help provide more equal access to learning and be in accordance with the needs of intellectual disabilities students. This was analyzed through Nvivo 11 where student response patterns showed that each principle of UDL was able to contribute to increasing the focus, engagement and ability of students intellectual disabilities in expressing the meaning of concepts optimally.

Meanwhile, the findings extend existing research by illustrating the role of UDL not only in enhancing engagement but also in facilitating conceptual access to chemistry topics that require high cognitive demand. The findings of the pretest and posttest before and after the implementation of UDL showed an increase in conceptual understanding for each student. DADH students gathered an N-gain score of 1.00, AHA 1.00, and E students 0.83, with an average N-gain of 0.93, which indicattes in high level of improvement. Refering to this analysis results, it shows that the learning experience built through the implementation of UDL not only facilitates learning comfort but also exerts an impact on the understanding of chemical concepts in the material on the periodic properties of elements. For future research, studies involving larger and more diverse student populations are recommended to further examine the effectiveness of UDL in chemistry education. Comprehensive assessment instruments would also be valuable in evaluating the sustainability and depth of conceptual understanding supported by UDL-based instruction.

Author Contributions

All authors made equal contributions to the preparation of this manuscript. In addition, each author read and approved the final manuscript prior to submission for publication.

Funding

This research was supported by funding from the Directorate of Research, Technology, and Community Service (DRTPM), Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, without involvement in the design of the research or preparation of the article.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

Acknowledgement

The authors would like to acknowledge to senior high school 10 Surabaya for permitting this research to be conducted. Special thanks are extended to the chemistry teacher, special eccompanying teacher (GPK), and students participated in this research.

References

Abels, S., Koliander, B., & Plotz, T. (2020). Conflicting demands of chemistry and inclusive teaching – A video-based case study. *Education Sciences, 10*(3), 50. https://doi.org/https://doi.org/10.3390/educsci10030050

Adi, Y. K., Widodo, A., & Sopandi, W. (2023). Students ' visual representation of lights and visions. *Jurnal Penelitian Pendidikan IPA, 9(*10), 8546–8553. https://doi.org/10.29303/jppipa.v9i10.5240

Agus Suradika, D. W. (2019). *Metode Penelitian UM Press*.pdf. Jakarta: UM Jakarta Press.

APA. (2013). *Diagnostic Statistical Manual Of Mental Disorders (DSM) (5th ed.; M. . Michael B. First, Ed.).* Washington, DC London, England: American Psychiatric Publishing.

Arduini, G. (2020). Curriculum innovation with Universal Design for Learning. *Education Sciences & Society, 11*(1), 90–103. https://doi.org/10.3280/ess1-2020oa9460

Bracken, S., & Novak, K. (Eds.). (2019). *Transforming higher education through universal design for learning: An international perspective.* New York: Routledge 2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN.

Browder, D. M., Spooner, F., Lo, Y., Saunders, A. F., Root, J. R., Davis, L. L., & Brosh, C. R. (2018). Teaching students with moderate intellectual disability to solve word problems. *Journal of Special Education, 51*(4), 222–235. https://doi.org/10.1177/0022466917721236

Cheon, K. A. (2024). Comprehensive understanding of slow learners (borderline intellectual functioning). *Journal of the Korean Academy of Child and Adolescent Psychiatry, 35(*3), 153–154. https://doi.org/10.5765/jkacap.240023

Connor, D. J., Cavendish, W., & Connor, D. J. (2018). ' Sit in my seat ': perspectives of students with learning disabilities about teacher effectiveness in high school inclusive classrooms inclusive classrooms. *International Journal of Inclusive Education*, *24*(3), 288-309. https://doi.org/10.1080/13603116.2018.1459888

Creswell, J. W. (2009). *Research design qualitative,quantitative, and mixed methods approaches (3rd editii).* Los Angeles: SAGE Publications.

Devita, D., Nurhidayati, Hardianti, D., & Desmayanasari, D. (2025). Learning process of fraction operations in students with intellectual disabilities. *Hipotenusa Journal of Research Mathematics Education (HJRME), 8*(1), 54–67. https://doi.org/10.36269/hjrme.v8i1.3160

Domenico, F., Blasi, D., Costanzo, A. A., Finocchiaro, M., Stimoli, M. A., Zuccarello, R., … Zoccolotti, P. (2023). Education sciences academic skills in students with autism spectrum disorder and intellectual disability : A systematic review and meta-analysis. *Education Sciences, 13*(10), 1026. https://doi.org/https://doi.org/10.3390/educsci13101026

Febriana, P. R. D. H. (2022). Teacher problems in learning children with special needs (ABK) at inclusive school SDN 1 selong. *Jurnal Progres Pendidikan, 3*(2), 115–120. https://doi.org/10.29303/prospek.v3i2.233

Febriyani, R., & Mayasari, E. (2025). Students' learning engagement in the topic of atomic concepts and the periodic table. *Hydrogen: Jurnal Kependidikan Kimia, 13*(4), 894-904. https://doi.org/https://doi.org/10.33394/hjkk.v13i4.16944

Hake, R. R. (1998). Interactive-engagement versus traditional methods : A six-thousand-student survey of mechanics test data for introductory physics courses Interactive-engagement versus traditional methods : A six-thousand-student survey of mechanics test data for introduc. *American Journal of Physics, 64*(1998), 64–74. https://doi.org/10.1119/1.18809

Hikmat. (2022). The implementation of inclusive education for children with special needs in indonesia. *Jurnal Ilmu Pendidikan, 4*(2), 1888–1896. https://doi.org/https://doi.org/10.31004/edukatif.v4i2.2338 Copyright

King sears, M. E., & Johnson, T. M. (2020). Universal Design for Learning Chemistry Instruction for Students With and Without Learning Disabilities. *Journal Remedial and Special Education, 41*(4), 207–218. https://doi.org/10.1177/0741932519862608

Kumar, P. (2025). Importance of early childhood education and its impact on children's cognitive and social development. *International Journal of Scientific Research in Science and Technology, 12*(3), 1082–1086. https://doi.org/https://doi.org/10.32628/IJSRST25123119

Lee, L., Canter, S., King, L. H., Williams, J. B., Metcalf, D., Rhys, K., & Potts, M. (2017). Evaluating pedagogy and practice of universal design for learning in public schools. *Exceptionality Education International, 27*(1), 1–16. https://doi.org/https://doi.org/10.5206/eei.v27i1.7743

Maryanti, R. (2021). Indonesian journal of community and assessment of mathematical abilities of students with intellectual disabilities during the COVID-19 pandemic. *Indonesian Journal of Community and Special Needs Education Journal, 1*(2), 47–52. https://doi.org/10.17509/ijcsne.v1i2.33402

Nurfadhillah, S., Anjani, A., Devianti, E., Suci Ramadhanty, N., & Amalia Mufidah, R. (2021). Lamban belajar (slow learner) dan cepat belajar (fast learner). *PENSA : Jurnal Pendidikan Dan Ilmu Sosial, 3*(3), 416–426. Retrieved from https://ejournal.stitpn.ac.id/index.php/pensa

Patel, D. R., Cabral, M. D., Ho, A., & Merrick, J. (2020). A clinical primer on intellectual disability. *Translational Pediatrics, 9*((Suppl 1)), S23–S35. https://doi.org/10.21037/tp.2020.02.02

Priliyanti, A., Muderawan, I. W., & Maryam, S. (2021). Analisis kesulitan belajar siswa dalam mempelajari kimia kelas XI. *Jurnal Pendidikan Kimia Undiksha, 5*(1), 11–18. https://doi.org/10.23887/jjpk.v5i1.32402

Priyadharsini, V., & Mary, R. S. (2024). Universal Design for Learning (UDL) in inclusive education : Accelerating learning for all. *International Journal of Arts, Science and Humanities OPEN, 11*(4), 145–150. https://doi.org/https://doi.org/10.34293/ sijash.v11i4.7489

Ramadhan, Y., & Nisa, K. R. (2020). Analysis of students misconception using Certainly of Response Index (CRI) in the periodic system of elements concept. *EduChemia (Jurnal Kimia Dan Pendidikan), 5*(2), 210–220. https://doi.org/10.30870/educhemia.v5i2.8285

Rosmi, Y. F., & Jauhari, M. N. (2022). Universal design for learning pada pembelajaran pendidikan jasmani adaptif di sekolah inklusi. *STAND: Journal Sports Teaching and Development, 3*(2), 40-48. https://doi.org/10.36456/j-stand.v3i2.7180

Saragih, D. E., Fitriani, Y., & Rochyadi, E. (2024). Asesmen pendidikan pada anak dengan slow learner. *Jurnal Inovasi, Evaluasi Dan Pengembangan Pembelajaran (JIEPP), 4*(3), 363–370. https://doi.org/10.54371/jiepp.v4i3.528

Szilagyi, D., & Albulescu, I. (2023). Inclusion of students with intellectual dizabilities in the mass: personalyzed intervention plan. *Educatia, 21*(25), 99–113. https://doi.org/10.24193/ed21.2023.25.11

Wulayalin, K. A., Suprihatiningrum, J., & Suprihatiningrum, J. (2024). Creating accessible chemistry content for students with disabilities : Findings from schools providing inclusive education in indonesia. *Jurnal Penelitian Pendidikan IPA, 10*(5), 2199–2210. https://doi.org/10.29303/jppipa.v10i5.6755

Zahran, M., Samsudin, A., Novia, H., Janeusse, N., Ningsih, D. T., Nugraha, E., & Nasbey, H. (2025). Post-pandemic e-teaching : Developing the Game for Microscopic Atom Simulation (GEMAS) to enhance students ' scientific conceptions of phase structures. *Journal of Environment and Sustainability Education, 3*(1), 115–126. https://doi.org/10.62672/joease.v3i1.55

.