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Enhancing slow learners' competency skills through e-LAPD using the UDL approach in clinical chemistry learning

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Abstract. The digitalization of chemistry education plays a crucial role in providing equal learning, this study is essential due to the persistent learning gaps experienced by slow learners in digital chemistry instruction. This study investigated the competency development of two slow learners at SMAN 10 Surabaya through the implementation of digital student worksheets (e-LAPD) focused on balancing chemical equations and Nomenclature of Ionic and Covalent bonds, combined with individualized strategies integrated with the UDL strategy delivered via the Liveworksheet platform. Qualitative data from semi-structured interviews and observations were analyzed using NVivo 11, comparing competencies at the start and end of the learning process. This analysis identified three key competencies: explaining scientific phenomena, interpreting data, and analyzing and evaluating scientific evidence. To supplement the qualitative results, pretest and posttest assessments were conducted, revealing significant improvements in competency. Specifically, students showed an average 40% increase in both the DA and E categories when balancing chemical equations. In contrast, for the Nomenclature of Ionic and Covalent bonds, DA scores rose by 80%, while E scores improved by 100%. The findings confirm that the use of e-LAPD with individualized learning strategies effectively promotes competency improvement among slow learners in chemistry education, guiding future instructional development.

Introduction

Educators have observed that some students lag significantly behind in mastering basic subjects and therefore require specialized assistance. Slow learners, generally possessing intelligence quotients ranging from 76 to 89, comprise approximately 8% of the overall school population. They do not appear markedly different from their peers, yet they process information more slowly and are often ridiculed for it. Although physically healthy, they tend to be less coordinated and somewhat clumsy. In class, they usually cause no behavioral issues and are cooperative, though much of the academic material exceeds their capacity (Chauhan, 2011). Children with intellectual disabilities can be classified based on the level of support they require in daily life (Marpaung & Simangunsong, 2023). Many also face emotional and environmental challenges that hinder their academic and personal growth. Despite their need for targeted support, most remain in regular classrooms without the individualized attention they require (Ridha, 2022). Their capacity for handling abstract and symbolic concepts such as numbers, language, and reasoning is limited, and they struggle with complex academic tasks and problem-solving situations (Widana et al., 2023). In education, such interventions may involve individualized learning plans as well as practical life skills training to improve everyday functioning (Cheon, 2024).

Although slow learners are typically in good physical health, they often display awkwardness and lack of coordination in their movements. In classroom settings, they rarely present behavioral or disciplinary issues, yet much of the academic material tends to exceed their learning capacity (Cleugh, 2021). While they are generally cooperative and show persistence, many encounter emotional and environmental challenges that impede both their learning progress and personal development. Ideally, such students should receive additional assistance through specialized programs within mainstream schools. However, in practice, most slow learners continue to study in regular classrooms without obtaining the individualized attention and support they genuinely need (Nugrahayati & Mustadi, 2019). Their reasoning skills in real-world scenarios are below average, and they have limited ability to deal with abstract and symbolic concepts (i.e., language, numbers, and ideas). The learning capacities of these students are marginally different from those of typical students (Imran et al., 2023). These results underscore the need for structural changes to create a more equitable and inclusive educational environment. The foundation of inclusive practices is the idea that schools and educational institutions have a duty to adapt curricula and instruction to suit a variety of student groups, making sure that the classroom environment complements their innate skills and capabilities (Ainscow, 2008; Evi Yupani & Widana, 2023). Every student contributes valuable assets to the classroom, including talents, strengths, and skills developed through personal experiences, knowledge, and beliefs. For slow learners, these resources may emerge more gradually but remain equally significant. Teachers who recognize and respond to the unique strengths and needs of their students, including those of students with special learning requirements, can more effectively adapt their teaching to support meaningful learning experiences (Petrou et al., 2009).

Fostering cohesion and democratic decision-making provides students with opportunities to express their views on teaching, learning approaches, and assessment. In this way, students' voices are acknowledged, valued, and integrated into the planning and organization of instruction. By embracing diversity as the norm and recognizing variations in learning styles, learning environments, and the use of learning materials, truly inclusive classrooms can be established (Sharma, 2024; Purnadewi & Widana, 2023). Teachers can utilize the Universal Design for Learning (UDL) paradigm when creating lesson plans to ensure student-centered learning and provide a variety of learning opportunities for diverse student groups, including those with learning difficulties (Rusconi & Squillaci, 2023). Traditionally, curricula are developed with certain students in mind, which creates barriers by excluding others who may then require additional support to succeed.

In contrast, Universal Design for Learning (UDL) represents an inclusive approach in which instructional materials and activities are intentionally designed to ensure that content is accessible to all students (Anastasiou et al., 2025). When developing lesson plans, educators can ensure student-centered learning and provide relevant learning opportunities for a range of student groups, including those with learning difficulties, by utilizing the Universal Design for Learning (UDL) paradigm (Gargiulo & Bouck, 2017). The architectural concept known as Universal Design for Learning (UDL) emphasizes the creation of structures, outdoor areas, products, and devices that consider diversity from the outset of the design process (Hall et al., 2012).

Learning resources, such as Student Worksheets and e-LAPD (Electronic Student Activity Sheets), are essential for helping teachers better understand students with intellectual disabilities, also known as slow learners, and for tracking their learning profiles over time more easily. A Student Worksheet (LAPD) serves as instructional material, incorporating content, summaries, and task guidelines, which enable students to engage with exercises aligned to basic competencies, thereby effectively achieving the targeted learning objectives (Safitri, 2022). Liveworksheet is a digital platform for student worksheets that provides interactive features to engage learners and support their mastery of basic competencies, thereby facilitating the achievement of learning objectives (Lestari et al., 2021). This approach not only helps them better understand the material but also enables the identification of their learning profiles through the learning process. Implementing individualized learning integrated with UDL learning in learning media is effective for supporting slow learner students by monitoring competency development (Mansor et al., 2019).

The competencies emphasized in the 21st Century cover three key dimensions: skills, character, and meta-learning. In terms of skills, students are required to exhibit creativity, critical thinking, clear communication, and the ability to collaborate effectively in groups (González & Ramírez, 2022). The character dimension encompasses qualities such as mindfulness, curiosity, courage, resilience, ethical values, and leadership. In addition, the meta-learning dimension highlights the significance of metacognition and the development of a growth mindset. Collectively, these competencies serve as crucial assets for students to confront the demands of the modern era, which require adaptability, innovation, and flexibility (Taylor et al., 2020; Jaya et al., 2025). Competence is a general statement about the knowledge and skills that students should possess after completing the learning process. From competence, more specific learning objectives are derived, and these objectives are further elaborated into measurable learning outcomes. In other words, competence indicates the general direction to be achieved, while learning outcomes serve as concrete evidence that the competence has actually been attained. To understand the changes in skill competencies, learning outcomes will be used to explain the results (Gonçalves et al., 2016). The skill competencies that need to be primarily developed. This research is particularly related to chemistry as one of the science subjects (Turiman et al., 2012; Sumanik et al., 2024). The implementation of equality for slow learners is widely promoted, but its implementation in schools remains limited (Imran et al., 2024). This gap between policy ideals and learning practices underlies this research, which focuses on improving the skills and competencies of slow learners through the implementation of UDL-based e-LAPD in chemistry learning.

The topic of balancing chemical equations is a fundamental concept in chemistry, requiring students to understand the quantitative relationships between substances involved in a reaction (Sastrohamidjojo, 2018). Balancing reactions involves applying the law of conservation of mass, where the number of atoms of each element on the reactant side must equal that on the product side (Akrosumah, 2016). However, in practice, many students encounter difficulties in learning this topic because it demands a high level of abstract thinking and symbolic representation. As a result, they often tend to memorize the balancing procedures without truly understanding their conceptual meaning. In addition, inaccuracy in identifying reaction coefficients, a lack of understanding of the law of conservation of mass, and weak basic mathematical skills are among the main factors contributing to students' errors (Reyes & Villanueva, 2024). For slow learners, these difficulties become even more complex due to their limitations in processing abstract information and reduced working memory capacity. Therefore, the learning process of balancing chemical equations should be designed adaptively using interactive media or worksheets that visualize the balancing steps progressively, helping students to comprehend the concept concretely (Korikana, 2020).

Similarly, the topic of naming ionic and covalent compounds is essential for students, but it also poses challenges for those who learn at a slower pace. Their limited working memory and slower information-processing speed make it difficult for them to connect symbolic concepts with real-world phenomena. Hence, adaptive learning strategies supported by interactive media, such as student worksheets or LiveWorksheet, are needed to help visualize the concepts and guide students through the learning steps systematically (Reyes & Villanueva, 2024; Panduwinata et al., 2025).

Students' difficulties, as shown in the questionnaire results indicating two internal factors influencing their challenges in learning chemistry: learning difficulties at 59.5%, interest in chemistry learning at 61%, and attitudes toward chemistry learning at 58% (Manurung & Kristianti, 2023). Previous studies that primarily aimed to enhance general conceptual understanding or digital literacy, this research emphasizes the importance of personalized scaffolding and interactive visual feedback tailored to the unique learning characteristics of students with learning difficulties, such as those who are slow learners (Evangelista et al., 2022). Through step-by-step and individualized digital learning experiences, this study seeks to enhance not only their understanding but also their overall competency and confidence in learning chemistry. The novelty of this research lies in the integration of LiveWorksheet-based adaptive learning strategies into clinical chemistry lessons to address the specific cognitive needs of students with learning difficulties. This approach focuses on helping students master both the balancing of chemical equations and the naming of ionic and covalent compounds.

Their importance lies in providing students with a strong conceptual foundation to develop scientific reasoning, problem-solving skills, and the ability to connect abstract concepts with real-world phenomena. For slow learners, mastery of these materials is essential, as it enables them to build structured knowledge step by step and supports their competency development in learning chemistry. Therefore, the findings from the pretest and posttest administered to the students as measurement tools were compared in order to conduct this research analysis. These instruments were designed to assess scientific competencies, comprising: (1) the capacity to interpret facts and scientific evidence; (2) the capacity to assess and plan scientific research; and (3) the capacity to explain scientific occurrences (Sutrisna & Anhar, 2020). Based on those explanations, the research questions of this study are: How do the skill competencies of slow learner students develop through their learning outcomes after engaging with the e-LAPD in balancing chemistry equations and non-mechanical ionic and covalent bonds? This research assumes that the use of e-LAPD combined with personalized teaching methods can improve students' skills in chemistry learning. Therefore, the objectives of this study were to analyze the progress of students who tend to lag in certain chemistry topics, identify shifts in the three scientific skills before and after the intervention, and consider the role of individualized strategies embedded in e-LAPD, while also developing suggestions for advancing digital and personalized learning in chemistry lessons.

Method

Research Method and Design

This study employed a mixed-method approach with concurrent embedded design types. The embedded model of research methodology combines quantitative and qualitative research methods simultaneously, but with differing weights. In this model, one method is primary while the other is secondary (Garcia et al., 2016). The primary method is used to gather essential data, while the secondary method is employed to support the data obtained from the primary method. This research selects qualitative data as its primary source, which will be supplemented by quantitative data (Almeida, 2018). The qualitative approach explored students' experiences, responses, and learning challenges during the use of e-LAPD, which were obtained through interviews and observations. At the same time, a quantitative approach was employed to assess the improvement in outcomes for slow learners through pretests and posttests. The integration of these approaches was considered appropriate to generate more comprehensive findings, as it not only emphasized numerical data but also provided more profound insights into the learning process and students' perspectives.

Several instruments were designed to collect both quantitative and qualitative data. The primary instrument was the e-LAPD, a digital student worksheet that focused on balancing chemical equations and non-mechanical ionic and covalent bonds. This worksheet supported individualized learning through structured activities aligned with the learning objectives. The individualized strategies incorporated three stages, namely engagement to increase motivation and interest, representation to present content in multiple accessible formats, and action and expression to allow diverse ways of demonstrating understanding. Pre- and posttests via Google Forms measured students' understanding at cognitive levels C2–C5 before and after using e-LAPD. Semi-structured interviews assessed usability, clarity, visual design, and conceptual understanding, while observation sheets recorded students' activities and responses during individualized learning stages.

The Qualitative data were collected from interviews and observation results, while the quantitative data were collected from pre-test and pos test results. Pre- and posttests via Google Forms measured students' understanding at cognitive levels C2–C5 before and after using e-LAPD. Semi-structured interviews assessed usability, clarity, visual design, and conceptual understanding, while observation sheets recorded students' activities and responses during individualized learning stages. Here is the explanation about the research subject and data analysis technique.

Research Procedure

e-LAPD was trialed through a pretest to assess the initial understanding of the two slow learner students regarding balancing of chemical equations and the naming of ionic and covalent compounds. Following the pretest, e-LAPD 1 was implemented, during which each student was accompanied by an observer who conducted interviews and observed the entire learning process. Students' engagement and responses were also recorded through video documentation. Interviews were conducted after e-LAPD 1 to explore students' experiences, difficulties, and understanding of the material. Next, e-LAPD 2 was applied, followed by interview 2 to gain further insights into students' learning experiences and comprehension. After completing both e-LAPDs and interviews, a posttest was administered to measure improvements in learning outcomes. The data, including test results and interview transcripts, were collected to analyze the improvement of students' competency skills and were analyzed both quantitatively and qualitatively.

Research Participants

This study was conducted at SMAN 10 Surabaya from August 04 to August 22, 2025. It focused on two 11th-grade students with intellectual disabilities who were categorized as slow learners. The identities of participants are described in Table 1. Slow learners generally possess intelligence quotients ranging from 76 to 89. Although these students with intellectual disabilities do not classify with an IQ below 70, these students exhibit difficulties in understanding material and specific characteristics indicative of intellectual disabilities. They often display hyperactivity and attention disorders, which lead them to focus more on physical activities rather than concentrating on the educator (Patel et al., 2020). Additionally, they may experience weaknesses in memory and thinking, including challenges in problem-solving and conceptualization. Furthermore, these students face difficulties in learning and academic perception.

Table 1. Students' Identities

Initial Name	Gender	Age	IQ	Types of Disability
DA	Male	17	108	Slow learner with ADHD
E	Female	18	87	Slow learner with physical disabilities

Data Analysis Techniques

The change in scientific competencies was also analyzed using NVivo 11 by applying a matrix coding query to determine the result of coding reference counts. The data are students' test results and interview results. Each Matrix Coding query generates a matrix, with the cells representing the intersections between the materials in the rows and those in the columns, offering virtually limitless possibilities for analysis (Mortelmans, 2025). The interview results, as well as students' pretest and posttest responses, were transcribed into written statements. Each statement was then analyzed using NVivo through a matrix coding query, in which the statements were mapped into three scientific competen11cy categories: (1) interpreting scientific facts and evidence, (2) planning and evaluating scientific investigations, and (3) explaining scientific phenomena. This process enabled a systematic analysis of students' understanding based on the distribution of their responses across the three competency categories.

The analysis was conducted by mapping these tendencies from the data sources, allowing the final results to be presented in a chart that shows the changes in students' initial skill competencies and their final skill competencies. The mapping process integrates students' explanations and data to reveal students' skill competencies as illustrated in Image 1.

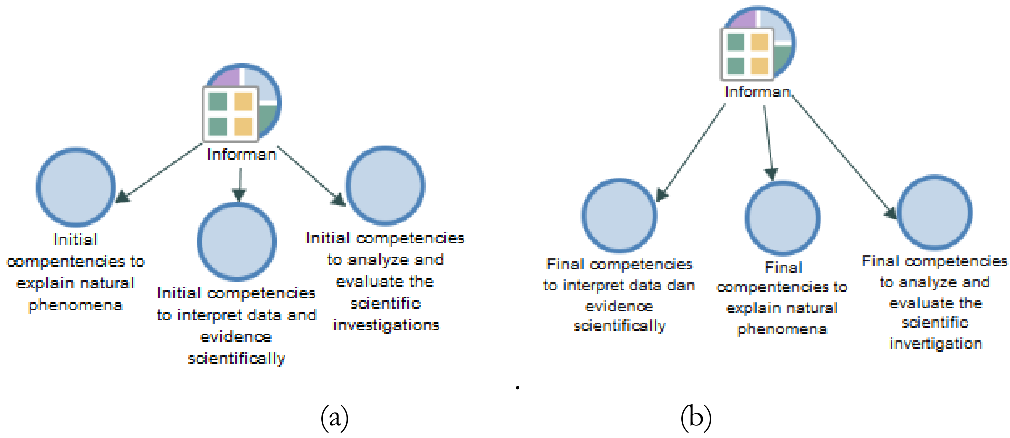

Image 1. Mapping process of analyzing (a) initial skill competencies changes and (b) final skill competencies.

In this study, data were obtained through students' interviews regarding the concept. Each response was scored on a scale of 0 to 4 according to the established indicators. These scores were subsequently converted into percentages (0–100%) for more precise interpretation. The conversion was calculated using the formula:

$$\text{Precentage} = \frac{\textit{Obtained Score}}{\textit{Maximum Score}} \text{ x } 100\%$$

Table 2. Category of score percentage

Score	Precentage	Category
0	0%	competence not demonstrated
1	25%	very low competence
2	50%	adequate competence
3	75%	good competence
4	100 %	very good/competent

The analysis results were reinforced by the students' pretest and posttest scores, as well as an examination of their responses, which reflected the attainment of skill competencies. Each student's understanding will be analyzed based on every test item indicator. The growth of students' skill competencies through e-LAPD learning was assessed by further analyzing the quantitative data from the pretest and posttest using individual percentage increase computations (Sukarelawan et al., 2024). The formula to determine the percentage is:

$$\frac{Posttest}{Maximal} \times 100\% - \frac{Pretest}{Maximal} \times 100\%$$

Results and Discussion

Through individualized learning utilizing the Universal Design for Learning (UDL) technique and Liveworksheet integration with the e-LAPD platform, this study seeks to investigate how students' competency skills in the subject of balancing chemistry equations and non-mechanical ionic and covalent bonds are developed. The changes in students' competencies will be analyzed for each chemistry topic, focusing on the development of skill competencies through observations and interviews. This analysis will be complemented by examining students' pretest and posttest responses. The data source can describe the students' skill competencies, including: (1) the ability to explain scientific phenomena, namely the skill to elaborate on atomic models in describing the properties or characteristics of matter; (2) the ability to interpret data; and (3) the ability to analyze and evaluate data and scientific evidence, namely the skill to analyze information, visual representations, and experimental data.

Analysis of Competences Changes in Balancing Chemical Equations.

The review and observation results were analyzed using NVivo 11 to determine the improvement in their competencies through their understanding of balancing chemical equations.

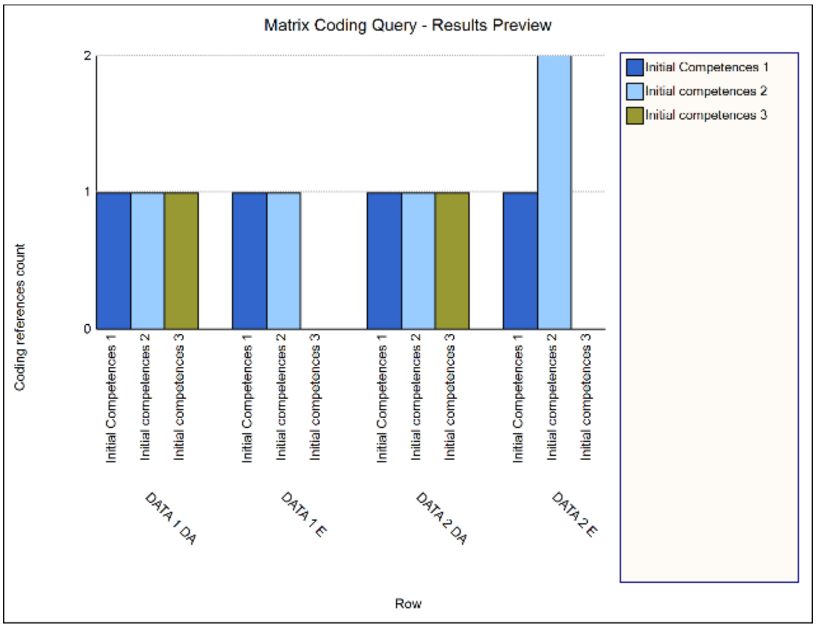

Image 2. Student's Initial Competencies Change in Balancing Chemical Equation

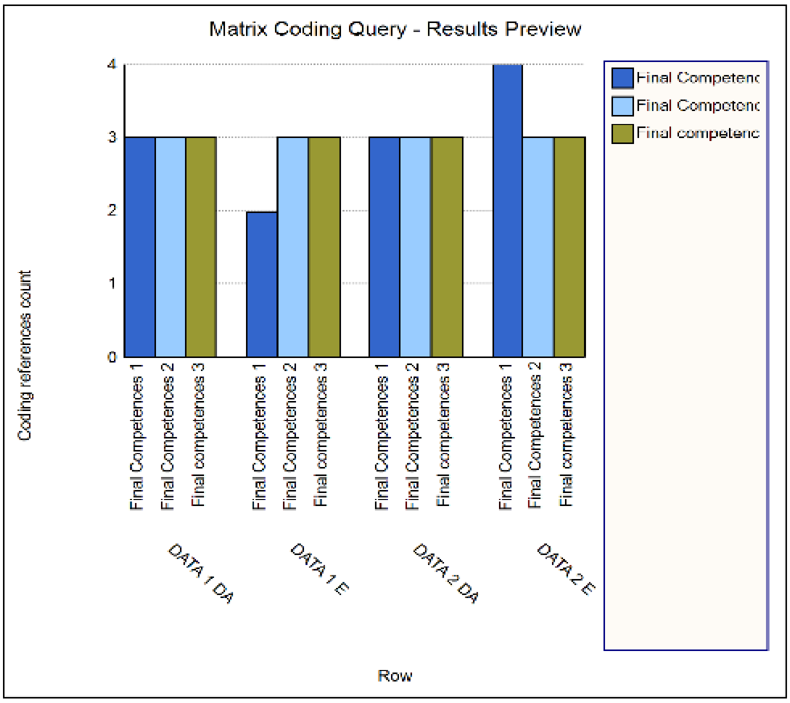

Image 3. Student's Final Competencies Change in Balancing Chemical Equation

Student DA

For Data 1 on understanding chemical equations, DA's initial competency across all three skills was 25%. In explaining phenomena, he could only recognize that a chemical equation represents a reaction, but he was unable to identify the roles of coefficients and subscripts. In interpreting data, he had difficulty reading the symbolic meaning of the equation, for example, distinguishing between the number of atoms and molecules. In analysis and evaluation, he also showed limited reasoning, unable to connect the equation with the law of conservation of mass. After completing E-LAPD, DA's performance improved. In explaining phenomena, he achieved 75%, demonstrating his ability to describe how a chemical equation represents reactants and products with specific atom ratios. In interpreting data, he also scored 75%, being able to recognize the number of atoms on each side of the equation. In analysis and evaluation, he achieved 75%, reasoning that equations must be balanced because matter cannot be created or destroyed. This finding aligns with research by Chittleborough & Treagust (2008) and can significantly enhance students' conceptual understanding of the symbolic and submicroscopic aspects of chemical reactions. To determine students' understanding of this concept, it was explored through questions that required students to write balanced chemical equations with simple coefficient ratios based on submicroscopic diagrams representing the reactions between reactants and products.

For Data 2 on balancing chemical equations, DA also started with low competency, at 25% for all three skills. In explaining phenomena, he only realized that equations "should be balanced," but he could not demonstrate how. In interpreting data, he struggled to identify imbalances, such as when atom counts differed between reactants and products. In analysis and evaluation, he could not explain why balancing is necessary to meet the conservation principle. After E-LAPD, DA progressed to 75% in each competency. He could explain that coefficients are adjusted to balance atoms, interpret chemical equations by checking atom counts systematically, and evaluate that balancing ensures the equation reflects real chemical processes. This improvement supports the findings of Wittmann et al. (2003), who reported that visual representations help students connect macroscopic observations with symbolic reasoning in chemical equations.

Student E
In Data 1 on understanding chemical equations, student E showed limited initial competence. For the first skill, he achieved only 25% since he merely recognized that a chemical equation shows a change of substances without a deeper explanation. After completing the E-LAPD, his score rose to 50% as he was able to explain more clearly that equations represent reactants and products. This pattern aligns with findings by Becker & Towns (2012), who noted that students often perceive chemical equations only as symbolic statements without linking them to underlying particle interactions. For the second skill, he also started at 25% because he could not interpret the relationship between symbols and the number of particles. With guidance, his score improved to 75% as he was able to connect coefficients with the number of atoms in an equation. Meanwhile, in the third skill, E scored 0% at first because he was unable to analyze and evaluate the significance of a chemical equation. After the e-LAPD, this improved to 75% since he could explain that chemical equations embody the law of conservation of mass and are crucial for reaction calculations. The conceptual teaching and representational support enhance students' understanding of conservation principles in chemical reactions (Hilton & Nichols, 2011; Ulliva & Prodjosantoso, 2025).

In Data 2 on balancing chemical equations, E's initial skills were also weak. For the first skill, he reached only 25% because he knew equations must be balanced, but could not explain why. After E-LAPD, this rose dramatically to 100% as he clearly explained that balancing is necessary to satisfy the law of conservation of mass. His improvement aligns with Fang et al. (2016), who reported that guided learning enhances students' ability to justify the necessity of balancing equations based on scientific reasoning. For the second skill, he began at 50% since he could recognize imbalances in simple reactions. After practice, his score improved to 75% as he could balance equations using coefficients, though he still struggled with more complex ones. For the third skill, he started at 0% because he could not evaluate whether an equation was balanced. After E-LAPD, he improved to 75% as he was able to assess the correctness of balanced equations and justify his choice of coefficients.

The improvement in students' scientific competency in balancing chemical equations is quite significant. This is evidenced by the increase in pretest and posttest scores represented in Table 3.

Table 3. Improvement percentage of pretest and posttest results in balancing chemical equations

Student	Pretest	Posttest	Improvement Percentage
DA	60	100	40%
E	60	100	40%

Analysis of Competences Changes in the Nomenclature of ionic and Covalent Bond
The interview and observation results from the learning process on the Nomenclature of ionic and covalent bonds were also analyzed using NVivo 11 to determine improvements in students' skill competencies.

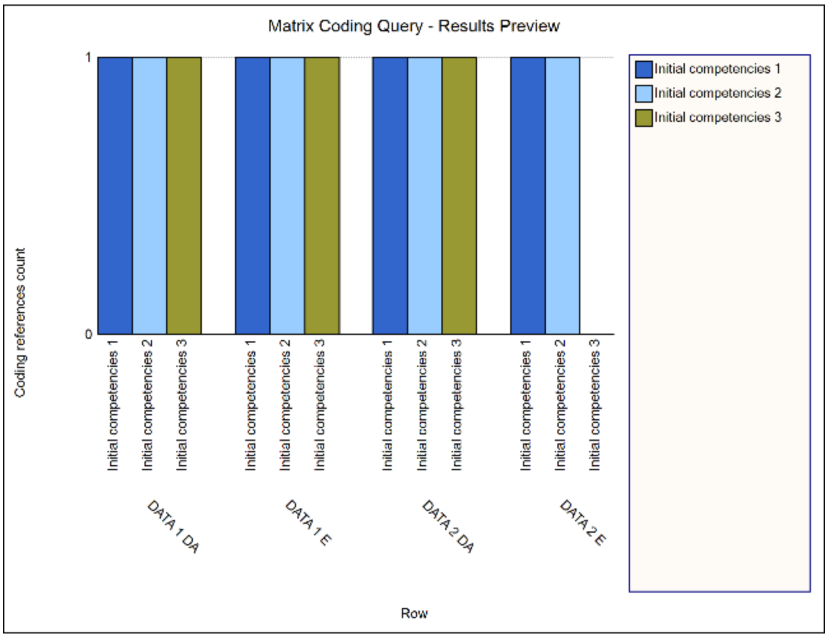

Image 4. Student's Initial competencies change in the Nomenclature of ionic and covalent bonds

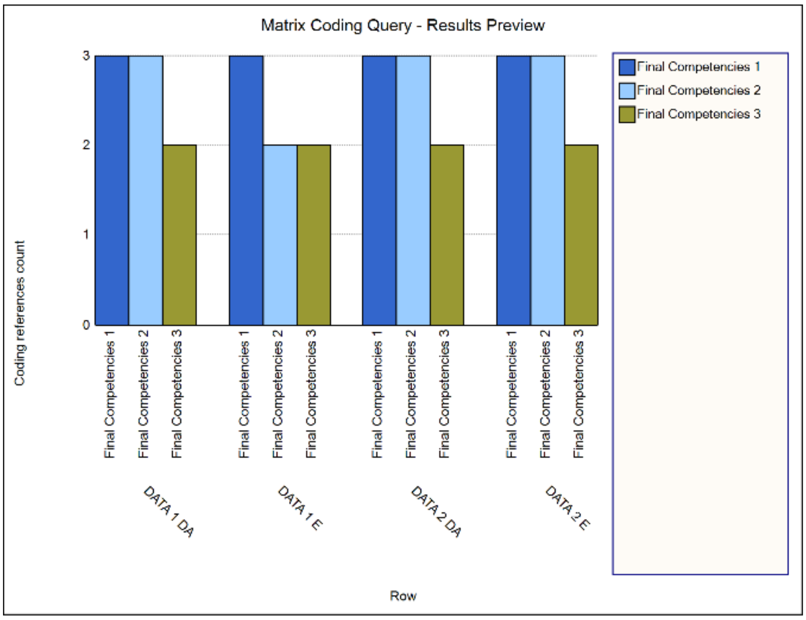

Image 5. Student's Final competencies change in the Nomenclature of ionic and covalent bonds

Student DA

In Data 1 on the Nomenclature of ionic compounds, student DA initially scored only 25% in skills 1, 2, and 3. For the first skill, explaining scientific phenomena, his answers were limited to mentioning simple examples without applying the systematic rules of ionic naming. After completing the e-LAPD, his performance improved to 75%, as he was able to explain the rules of cation and anion naming more clearly. For the second skill, interpreting data, he also started at 25% because he had difficulty translating chemical symbols into correct compound names. After e-LAPD, his score improved to 75%, as he was able to interpret chemical formulas into names with more accuracy. Meanwhile, in the third skill, analyzing and evaluating data, he scored 25% initially because he could not assess the correctness of compound names. After e-LAPD, his performance rose to 50%, showing that he was beginning to evaluate naming accuracy, though his reasoning was still limited.

Various factors contribute to the difficulties students face in the learning process. These challenges can generally be classified into two categories: internal and external factors. Internal factors include students' interest and motivation, while external factors involve influences from family, school, community, and the learning materials used in chemistry. Specifically, students' learning difficulties often stem from low interest and motivation, as well as limited variation in instructional media and teaching methods (Putri & Dj, 2022). These factors can be addressed through the use of the interactive e-LAPD that has been developed, which allows for the enhancement and observation of students' skill competencies in Data 2.

In Data 2 on the Nomenclature of covalent compounds, student DA again started with 25% in all three skills. At first, he was only able to identify atomic symbols without constructing proper covalent names. After E-LAPD, his performance improved significantly. For the first and second skills, his scores increased to 75% as he was able to explain the rules of naming covalent compounds and interpret molecular formulas with better accuracy. For the third skill, analyzing and evaluating, his performance rose to 50%, showing that while he could begin to evaluate the correctness of covalent names, his reasoning and consistency were still developing. interactive and student-centered approaches can significantly reduce misconceptions in learning chemical nomenclature and symbolic chemistry (Horzum & Aydemir, 2014).

Student E

In Data 1 on the Nomenclature of ionic compounds, student E initially scored only 25% in skills 1, 2, and 3. For the first skill, explaining scientific phenomena, he was only able to mention a few names of simple compounds without applying the rules of ionic naming correctly. After completing the e-LAPD, his performance improved to 75% as he could explain the basic naming rules for cations and anions more clearly. For the second skill, interpreting data, he also scored 25% at first because he struggled to translate chemical symbols into compound names. Learners are not able to fully understand chemical formula writing and naming; the tendency is that they will struggle in learning concepts related to stoichiometry, chemical reactions, and balancing equations, among others (Deleña & Marasigan, 2023). After e-LAPD, his performance improved to 50%, as he was able to interpret formulas of simple compounds with moderate accuracy. Similarly, in the third skill, analyzing and evaluating data, he began with 25% since he could not assess whether compound names were correct or not. After e-LAPD, his performance rose to 50% because he could evaluate the correctness of naming in basic cases, though with limited reasoning.

In Data 2 on the Nomenclature of covalent compounds, student E also showed low initial achievement, with 25% in skills 1 and 2, and 0% in skill 3. In the first skill, explaining scientific phenomena, he was only able to mention atom names without forming correct covalent compound names. After e-LAPD, his performance improved to 75% as he could explain and apply the rules of naming covalent compounds, although his explanations were still simple. For the second skill, interpreting data, he initially scored 25% because he struggled to interpret molecular formulas. After ELAPD, his performance increased to 75% as he was able to interpret names based on given molecular structures. Meanwhile, in the third skill, analyzing and evaluating data, he scored 0% initially since he could not differentiate or assess naming conventions. After e-LAPD, his performance improved to 50%, as he was able to begin evaluating the correctness of covalent compound names, though his reasoning was still developing. So it can be concluded that the use of conceptual models supports learners' visualization and retention of naming rules for molecular compounds and demonstrated that digital and game-based tools enhance engagement and accuracy in learning chemical nomenclature (Busalim et al., 2019).

The improvement in students' scientific competency in the topic nomenclature of ionic and covalent bonds is quite significant. This is evidenced by the increase in pretest and posttest scores represented in Table 4.

Table 4. Improvement percentage of pretest and posttest results of the Nomenclature of ionic and covalent bonds

Student	Pretest	Posttest	Improvement Percentage
DA	20	100	80%
E	0	100	100%

The change in pretest and posttest scores indicates a very substantial improvement. During the pretest, students experienced difficulty recalling previously learned chemistry material, which resulted in poor performance when answering the test questions, even though the content had been taught earlier in Grade 10. This suggests limitations in memory retention and conceptual recall, which are common characteristics of slow learner students. However, following the implementation of e-LAPD, students demonstrated a deeper understanding of the material. The use of e-LAPD supported students in revisiting and reinforcing prior chemistry concepts through structured scaffolding and step-by-step learning activities. In addition, the visual features and animations embedded in the e-LAPD increased students' motivation and engagement, thereby enhancing their ability to recall and comprehend the material. Consequently, these factors contributed to the significant improvement observed in the posttest scores. The results of the above research are quite relevant to previous research in which improving the abilities of slow learner students can be done with several strategies that can be done by a teacher such as teacher strategies in class management with specifications and qualifications for changes in student behavior and personality (Wahyuningsih & Suranti, 2023; Widana, 2022), which in this study is using a universal design learning strategy with this strategy integrated in e-LAPD can improve the understanding of slow learner students in chemistry material, especially in the material on balancing chemical reactions and adding covalent and ionic compounds. Then the teacher's strategy in motivating slow learner students can facilitate learning because high learning enthusiasm increases students' curiosity in deepening chemical concepts (Amri et al., 2022). In the e-LAPD that we implemented in this study, we present animations and interactive features that can facilitate the depiction of chemical concepts for students and increase student learning motivation.

This study uses Liveworksheet-supported e-LAPD digital modules in conjunction with Universal Design for Learning (UDL) based individualized instruction to methodically assess how students' scientific competencies in chemistry, especially those of slow learners, are developing. By combining quantitative pretest–posttest data with qualitative NVivo-based analysis of observations and interviews, this study offers a fine-grained analysis of competency growth across three specific scientific skills: explaining phenomena, interpreting data, and analyzing and evaluating scientific evidence, in contrast to earlier research that mainly concentrated on teaching strategies or learning outcomes in general. This mixed, competency-oriented approach advances inclusive and technology-enhanced chemistry education research methodologically and pedagogically by providing fresh perspectives on how adaptive digital learning environments can scaffold conceptual understanding and reasoning in abstract chemistry topics.

The findings of this study have significant theoretical and practical ramifications for the teaching of chemistry, especially for inclusive and digital learning. By offering empirical evidence that UDL-based individualized instruction, when combined with interactive digital platforms like Liveworksheet and e-LAPD, effectively supports the development of scientific competencies explaining phenomena, interpreting data, and analyzing and evaluating evidenceamong slow learner students in abstract chemistry topics, this study theoretically strengthens and expands the Universal

Design for Learning (UDL) framework. Using digital worksheets and adaptive tasks to lower misconceptions and learning barriers, the study provides teachers with a tangible instructional model to create inclusive, student-centered chemistry learning environments. Additionally, it offers guidance to educators and curriculum designers on how to implement differentiated instruction that is in line with UDL principles. This helps to support the successful participation of slow learners in mainstream science classrooms and contributes to more equitable chemistry learning opportunities.

Conclusion

The results of interviews and classroom observations on students' responses during e-LAPD activities showed a clear improvement in learning engagement, conceptual understanding, and scientific reasoning skills. Students appeared more confident in explaining chemical phenomena, interpreting data, and evaluating experimental results after participating in this adaptive digital-based learning process. These qualitative findings were further supported by the NVivo analysis using coding query matrices, which indicated that the implementation of e-LAPD combined with the Universal Design for Learning (UDL) strategy effectively enhanced students' overall scientific competencies. In line with these findings, quantitative data from the pretest and posttest also demonstrated significant improvement. Based on these findings, it is recommended that chemistry teachers implement UDL-oriented digital learning tools such as e-LAPD to accommodate diverse learner needs, especially for students who experience learning difficulties. Future research is suggested to explore the application of this approach across broader chemistry topics and student populations, as well as to investigate its long-term impact on students' scientific literacy and independent learning skills.

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