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THE INFLUENCE OF GENDER AND PROBLEM-BASED LEARNING MODEL ON STUDENTS' NUMERICAL LITERACY IN CHEMISTRY

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ABSTRACT

Chemical numeracy is essential for understanding quantitative concepts in chemistry; however, there are indications of achievement gaps between male and female students. This study aims to analyze the influence of gender on students' numeracy skills when implementing the Problem-Based Learning (PBL) model. This study employed a quasi-experimental design with a nonequivalent control group. The study population consisted of Phase F students at three high schools in West Sumatra, Indonesia. The sample comprised 188 students selected through purposive sampling based on initial ability equivalence. The research sample came from three schools, each serving as a research context for different topics: salt hydrolysis (experimental class = 33; control class = 30), reaction rates (experimental class = 35; control class = 35), and chemical equilibrium (experimental class = 26; control class = 29). The research instrument consisted of a chemistry numerical literacy test on reaction rates, chemical equilibrium, and salt hydrolysis, which experts had validated. Instruction in the experimental classes used the PBL model, while the control classes used conventional instruction, as typically implemented in schools. Data were analyzed using the N-gain test, normality test, homogeneity test, and Two-Way ANOVA. Results showed that improvement in numerical literacy in chemistry was greater in PBL classes than in control classes. Statistical analysis indicated that the PBL model had a significant effect on improving numerical literacy in chemistry. Gender was significant in only one school, and the interaction between the learning model and gender was also significant there, suggesting that the model's effectiveness may vary by context. These findings indicate that PBL is effective in enhancing students' numerical literacy in chemistry and imply that chemistry instruction should be designed around problem-solving approaches to develop quantitative reasoning and a contextual understanding of chemical concepts.

Keywords: gender; numerical literacy; chemistry learning; problem-based learning

INTRODUCTION

21st-century education emphasizes the integration of character development, literacy skills, practical skills, technology use, and knowledge mastery (Maulidia et al., 2023; Shaber et al., 2025). This concept aligns with the fourth Sustainable Development Goal (SDG), which focuses on providing quality, inclusive, and equitable education; developing skills aligned with the needs of the future world of work; mastering technology; and upholding the principles of sustainable development. It also serves as the foundation for the view that quality education is a fundamental right and the key to national development. More specifically, Target 4.6 of the fourth SDG aims to ensure that by 2030, all adolescents and a certain proportion of adults, both men and women, have literacy and numeracy skills (Bappenas, 2024).

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In this context, numerical literacy has become an essential competency in 21st-century learning because it involves using numbers and mathematical symbols to solve problems across a range of daily contexts. Numerical literacy requires not only the ability to calculate but also to analyze quantitative information, interpret data, and make logical and appropriate decisions. However, Indonesian students' numerical literacy achievement is still relatively low. The results of the 2022 Programme for International Student Assessment (PISA) show that Indonesia ranks 73rd out of 80 countries with a score of 379, far below the OECD average score of 487 (OECD, 2023). This data shows a significant gap between the global demands of 21st-century education and students' numeracy and literacy skills in Indonesia, underscoring the need for more effective, context-based learning efforts. In chemistry education, numerical literacy is critical because many chemical concepts require quantitative analytical skills, such as stoichiometry, reaction rates, chemical equilibrium, and the interpretation of graphs and experimental data. These skills enable students to integrate chemical concepts with mathematical reasoning to understand scientific phenomena and solve data-driven problems (Chi et al., 2024; Altindis et al., 2024). Several studies also indicate that integrating numerical literacy into chemistry instruction can enhance students' conceptual understanding and data analysis skills (Cahyana et al., 2023; A'yuni & Ardhana, 2024).

To address this gap, a learning model is needed that can train students' quantitative analysis and contextual problem-solving skills. One learning model for chemistry instruction is Problem-Based Learning (PBL). The PBL model emphasizes students' active involvement in solving contextual problems through critical, analytical, and reflective thinking (Qondias et al., 2022). Through PBL, students are encouraged to construct knowledge independently and collaboratively, in line with 21st-century skills such as critical thinking, communication, and collaboration (Suyato et al., 2024). Several studies show that PBL can improve students' learning outcomes (Almagribi et al., 2024), critical thinking skills (Lubna et al., 2023), and science literacy (Asda et al., 2023). These findings indicate that PBL has strong potential in supporting the improvement of numerical literacy (Martiana et al., 2025), especially when applied to chemistry learning that requires quantitative analysis skills. Previous research has also demonstrated that the PBL approach can improve students' abilities to analyze data, interpret quantitative information, and solve context-based problems through investigative and collaborative discussion processes (Chang et al., 2022; Hidayatullah & Setiawan, 2024; Salim et al., 2024). Furthermore, PBL encourages students to integrate conceptual knowledge with mathematical reasoning in addressing scientific problems, thereby strengthening numerical literacy in science learning (Rahma et al., 2025).

Along with the characteristics of PBL that require students' active involvement in solving contextual problems, the application of this model requires a learning environment that facilitates information exploration, data analysis, and effective collaboration (Fausan et al., 2021). In the context of 21st-century learning, this need is increasingly relevant with the use of digital technology as a learning support tool, because technology allows for the presentation of problems, data, and learning resources in a more varied, interactive, and accessible way for students (Moliner et al., 2021; Razak et al., 2022; Kumalasari et al., 2024).

The integration of technology into learning makes learning more flexible and accessible, allowing it to be used on smartphones anytime, anywhere with an internet connection (Zigh et al., 2022; Rashid & Howard, 2023; Abusamra, 2024; Aliyyah et al., 2024; Nur et al., 2024). The use of information technology in teaching materials can help students absorb information (Rachmadtullah et al., 2023), enhance learning experiences (Simbolon & Febrianti, 2020), improve learning outcomes (Jasrial et al., 2023), and develop students' communication skills (Yermekbayeva et al., 2024). The use of technology in learning can foster important 21st-century skills such as problem solving, collaboration, creativity, and HOTS in students (Zainil et al., 2023; Kuncoro et al., 2025; Rangkuti et al., 2025), as well as increasing students' self-efficacy and learning achievement (Fitriyana et al., 2020). Digital technology-based learning also creates a more engaging learning experience, thereby increasing student engagement and strengthening the role of teachers, schools, and parents in optimizing student learning outcomes (Sumardi & Muamaroh, 2020; Bakhsh et al., 2022; Khaeruddin, 2025). However, integrating digital technology with the right learning model not only increases learning engagement but also develops students' contextual numerical literacy in chemistry.

In line with this, PBL is one of the learning models that is relevant for implementation in digital learning (Rudolphi-Solero et al., 2025). PBL encourages students to actively solve contextual problems through critical, analytical, and reflective thinking processes, both independently and collaboratively. The use of PBL-based digital platforms has been proven to improve critical thinking skills (Suharno & Setyarini, 2021; Kristiantari et al., 2022; Suresman et al., 2023; Fongkanta & Buakanok, 2024), interest and learning achievement (Choo & Taha, 2023), reasoning (Fitrawati et al., 2023), and students' problem-solving abilities (Manurung & Panggabean, 2020). In addition, integrating PBL-based learning media in a digital environment can improve students' digital literacy (Perdana et al., 2020). However, studies on PBL in digital learning are still dominated by a focus on the development of general cognitive skills, while its role in supporting numerical literacy integrated into chemistry learning is still relatively limited.

Although many studies have examined students' numeracy or mathematical literacy, they generally focus on general mathematical achievement and large-scale assessment rather than on numerical literacy integrated into the learning of specific subjects such as chemistry (OECD, 2023; Shanahan & Shanahan, 2008). Research in chemistry education also tends to examine problem-based learning and digital resources such as e-modules separately, with little attention to how combining the two can support students' numerical literacy (Gazali et al., 2025; Islamiati & Redhana, 2025). Furthermore, findings on gender differences in numeracy and chemistry-related achievement vary across contexts, and very few studies explore whether male and female students benefit differently from problem-based learning supported by chemistry e-modules (Odom et al., 2021). A study on gender and digital instructional tools in chemistry education found inconsistent or insignificant interaction effects, highlighting a gap in research on how interventions provide different benefits for different genders (Oladejo et al., 2021). Furthermore, in the Indonesian context, research exploring how gender affects numerical literacy when digital chemistry modules are used remains limited (Marsila et al., 2025). Findings from other countries may not be directly applicable, as gender-related learning outcomes can vary across socio-cultural contexts (Guo et al., 2024). This leaves a gap in understanding how teaching models and digital materials interact with gender to influence students' numerical literacy in the context of chemistry.

Furthermore, gender is also an important factor that greatly influences the learning process (Sucipto et al., 2023; Anwar et al., 2024; Pineda et al., 2025). Gender also greatly influences students' cognitive abilities (Kawuryan et al., 2021; Wahyudi et al., 2024), reading interest (Sultan et al., 2020), writing skills (Nggawu, 2024), and the ability to express arguments (Ningrum & Crosthwaite, 2020). Therefore, it can be stated that gender significantly influences students' interaction and learning methods in an educational environment (Rusydiyah et al., 2024). Gender also plays a role in students' tendencies toward certain abilities, including numerical literacy. Previous studies have shown that men's literacy skills are superior to women's, while women's numeracy skills are superior to men's (Lukman, 2023). In line with this, other findings also show that women's numeracy skills are better than men's (Suprawata & Riastini, 2022). The study shows differences in numerical literacy tendencies between men and women. Moreover, in the context of science education, several studies have shown that gender can influence students' interest, self-efficacy, and participation in learning analytically and quantitatively oriented science concepts (Aguillon et al., 2020; Kucuk & Sisman, 2020; Wang et al., 2023). Given these differences, teacher responsiveness to gender-related patterns is essential to creating an inclusive and equitable learning environment. This pedagogical approach supports equity as outlined in the Sustainable Development Goals (SDGs), particularly SDG 4, and reflects the principles of gender equality in teaching and learning.

However, existing studies generally examine gender and learning models separately (Mangubat & Mangubat Jr, 2025), thus failing to provide a complete picture of the interaction between gender and the application of PBL in improving students' numerical literacy in chemistry. Studies that specifically examine the simultaneous influence of gender and PBL on numerical literacy are still limited, especially in the context of chemistry learning. In fact, numerical literacy is an essential 21st-century skill that requires integrating mathematical reasoning, contextual problem-solving, and appropriate learning strategies. This condition highlights a research gap in the PBL model regarding gender differences in improving students' numerical literacy in chemistry learning. Thus, the uniqueness of this study lies in its attempt to simultaneously analyze the effects of implementing the PBL model and gender factors on improving students' chemical numeracy, thereby providing a more comprehensive understanding of the role of learning models and gender differences in the development of numeracy skills in chemistry education.

Based on the background discussed, one approach to improving students' numeracy and literacy skills is to implement a learning model supported by relevant, inclusive materials that account for gender differences and cultural contexts. This approach contributes to greater equity in teaching and learning. Therefore, research is needed to examine the influence of gender on the application of the PBL model on improving students' numerical literacy, so that it can complement, strengthen, and expand on previous research findings, while providing empirical contributions to the development of inclusive, equitable chemistry learning that is in line with the Sustainable Development Goals (SDGs), particularly SDG 4 on quality education oriented towards 21st-century learning demands and SDG-5 on gender equality.

Based on the background above, the research question for this study is: Is the numerical literacy of students taught using the PBL model influenced by gender?

METHODS

This quasi-experimental study used a nonequivalent control group design. The population for this study consists of all students in Phase F at SMAN X, SMAN Y, and SMAN Z who are taking chemistry. The sample schools were selected based on several criteria. First, these schools implement the same curriculum, namely the Merdeka Curriculum. Second, the schools have similar levels of academic achievement. Third, there were chemistry teachers available who were willing to implement the PBL model.

Furthermore, classes were selected based on their previous average chemistry performance. The research sample consisted of experimental and control classes selected through purposive sampling. Purposive sampling was used because respondents were selected based on specific criteria aligned with the research objectives and variables. In quantitative research, this technique is used to ensure that the sample possesses characteristics relevant to the hypothesis being tested, thereby making the analysis results more accurate and valid within the study's context (Memon et al., 2025).

The research instruments used include a chemistry numerical literacy test covering reaction rates, chemical equilibrium, and salt hydrolysis. Before use in the study, the instruments were tested for validity and reliability. The validity test results showed that there were 22 valid items for the reaction rate material, 16 for the chemical equilibrium material, and 13 for the salt hydrolysis material. Furthermore, the reliability test using the r_{11} coefficient yielded values of 0.753 for the reaction rate topic, 0.90 for the chemical equilibrium topic, and 0.67 for the salt hydrolysis topic. Based on reliability criteria, these values indicate that the instrument has high reliability for the reaction rate and chemical equilibrium topics and adequate reliability for the salt hydrolysis topic; thus, the instrument is deemed suitable and consistent for use as a data collection tool in the study.

In the questions on reaction rate, students were asked to analyze data on concentration changes over time to determine the reaction rate and interpret its quantitative meaning. In the questions on chemical equilibrium, students were asked to calculate the equilibrium constant (Kc) from equilibrium concentration data and to interpret its implications for the direction of the reaction shift. Meanwhile, in the material on salt hydrolysis, students are asked to determine solution properties and calculate pH using the relevant hydrolysis equation. These items were designed to measure numerical literacy in chemistry, particularly in reading and processing numerical data, applying mathematical concepts in a chemical context, and interpreting calculation results logically and contextually. These questions were then used to assess students' numerical literacy in the experimental and control classes.

The study began with a pretest administered to both the experimental and control classes. The experimental class was taught using the PBL model, while the control class implemented the conventional learning model typically used in schools. In the experimental class, learning was conducted according to the PBL syntax, beginning with orienting students to the problem through the presentation of contextual problems relevant to the material (Jansson et al., 2015). Students were then organized into small groups to identify facts, formulate problems, and set learning objectives. Next, during the investigation stage, students collected and processed information individually and collaboratively, with the teacher serving as a facilitator. The investigation was conducted as group presentations to obtain feedback and reinforce concepts, and concluded with an analysis and evaluation of the problem-solving process and results to deepen conceptual understanding. The learning intervention in both classes covered three materials: chemical equilibrium (10 lessons), reaction rate (10 lessons), and salt hydrolysis (7 lessons), for a total of 27 lessons (each lasting 45 minutes). After the entire learning series in both classes was completed, a posttest was administered to assess students' learning outcomes following the treatment and to compare improvement in ability between the experimental and control classes.

The results of students' numerical literacy in chemistry were analyzed using the N-Gain formula, the normality test, the homogeneity test, and the hypothesis test (Fraenkel & Wallen, 1990). Data on students' numerical literacy in chemistry skills were obtained by comparing pretest and posttest scores in each sample class. The N-Gain interpretation results can determine the level of numerical literacy in chemistry using the PBL model in the high, medium, and low categories. For the normality test, the Kolmogorov-Smirnov and Lilliefors tests were used. The data were declared normally distributed if D-calculated< D-table or L-calculated < L-table. The homogeneity test was performed using the F (Fisher) test. The data were declared homogeneous if F-calculated < F-table.

The hypothesis test was formulated as a statistical hypothesis. This hypothesis test aims to determine whether the research hypothesis is accepted or rejected. This hypothesis test uses the formula H1: $\mu 1 \neq \mu 2$. H1is accepted if there is a difference in the numerical literacy in chemistry of students who learn using the PBL model (experimental class) from those who do not use the PBL model (control class). Hypothesis testing was conducted using a Two-Way ANOVA to examine the effects of gender and the PBL model on improvements in numerical literacy in chemistry across the three research schools, including the entire data processing and analysis process.

Table 1 shows the relationship between the learning model and gender. The learning models in this study consisted of Problem-Based Learning (PBL) and non-PBL. PBL refers to learning using the PBL model applied in the experimental class, while non-PBL refers to learning not using the PBL model applied in the control class. Gender is divided into two categories: male and female. In this table, the X-axis represents the learning model and the Y-axis represents gender. Thus, the two axes interact to illustrate the treatment combinations in each group. The test design is shown in Table 1.

Table 1. Two-Way ANOVA Design

Gender/ Model	PBL	Non-PBL
Male	A1B1	A1B2
Female	A2B1	A2B2

This design was applied to data analysis in each school. AB represents numerical literacy in chemistry. Code A1B1 indicates the numerical literacy in chemistry of male students who use the PBL model. Code A1B2 indicates the numerical literacy in chemistry of male students who follow non-PBL. A2B1 indicates the numerical literacy in chemistry of female students who use the PBL model. Code A2B2 indicates the numerical literacy in chemistry of female students who follow non-PBL.

RESULTS AND DISCUSSION

Based on the research, data on students' numerical literacy in chemistry were obtained, as shown in Figure 1.

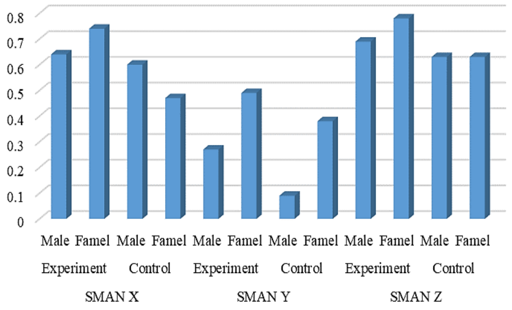

Figure 1. N-Gain Test Results

Based on Figure 1, students' N-Gain scores indicate differences in learning gains by sample class and gender (male and female) at SMAN X, SMAN Y, and SMAN Z. At each school, the N-Gain scores of male and female students in the experimental and control classes show variation across categories. Based on the N-Gain interpretation criteria, improvements in student ability can be categorized into three levels: low, moderate, and high. Analysis results indicate that most N-Gain scores fall within the moderate to high categories, particularly in the experimental classes, whereas in the control classes, some scores remain in the low to moderate categories. This suggests that improvements in students' numerical literacy in chemistry in the experimental classes tend to be better than those in the control classes. These variations in numerical literacy in chemistry improvements are related to the characteristics of the chemistry materials used in the assessment. This material requires numeracy skills through the use of numbers and symbols, data analysis in the form of tables and graphs, and the interpretation of calculation results for decision-making. Thus, the N-Gain scores obtained by the students reflect their ability to solve quantitative chemistry problems in accordance with numeracy indicators.

The findings of improved numerical literacy through the application of the PBL model in this study are in line with previous research results, which show that students taught through the PBL model have higher numerical literacy improvement compared to students taught without the PBL model (conventional), both in terms of N-Gain scores and statistical test results (Awami et al., 2022; Imala et al., 2024). Other studies also show that integrating PBL into science learning can encourage students to develop quantitative thinking skills through data analysis, the use of mathematical symbols, and the interpretation of calculation results in the context of solving real problems. This reinforces the finding that the improvement in students' chemistry numerical literacy in the experimental class is inseparable from the characteristics of PBL, which emphasize active engagement and contextual problem-solving.

Numerical literacy is evident in the material on reaction rates. The material on reaction rates is one of the materials related to chemical calculations, namely, determining the reaction rate equation and the reaction order. In the reaction rate equation, symbols and numbers are used; in the order of reaction, reaction order graphs are applied; and in determining the reaction rate equation, experimental data are presented in tabular form. This relates to indicators of numerical literacy, namely using various numbers and symbols in basic mathematics to solve problems in daily life, analyzing information presented in various forms, and interpreting the results of the analysis to predict and make decisions (Kemdikbud, 2017; Pusmenjar, 2020).

One example of a chemistry numerical literacy question on reaction rates is asking students to determine the reaction rate equation by first determining the reaction order. Students determine the reaction order against Q (x) at the same T. Students then determine the reaction order against T (y) by finding the same Q concentration. After the reaction order is determined, students can determine the reaction rate equation using $r = k [A]^x[B]^y$ (Chang, 2011). Based on the answers, students can determine the reaction rate equation from the tabular data. This means that students can read quantitative data in tables and work with numbers or chemical symbols to determine the reaction rate equation, demonstrating numerical literacy in chemistry. Therefore, applying the PBL model to reaction rate materials can help improve students' numerical literacy in chemistry. In implementing the PBL model in reaction rate learning, students are guided through PBL syntax to solve problems. The first syntax concerns students' orientation to the problem, which can be presented as images, discourse, or barcodes containing videos or audio. The problems presented are contextual problems that will be observed and understood by students. The second syntax is organizing students to learn, where students discuss in groups to find the information needed to solve the problems presented. The third syntax guides individual and group investigations, in which students find information from various sources or references to solve problems. This syntax presents material on reaction rate equations and reaction orders, demonstrating the use of numbers and symbols from basic mathematics, as well as reaction rate and reaction order graphs and experimental data presented in tabular form. This shows that this syntax supports students' numerical literacy in chemistry skills. The fourth syntax is developing and presenting work results, where students produce discussion results by working on reaction rate material questions related to calculations. Questions about the use of numbers and symbols can support students' numerical literacy in chemistry. The last syntax is analyzing and evaluating the problem-solving process, where students find solutions to problems and draw conclusions. The existence of PBL model syntaxes related to numerical literacy indicates that the PBL model can support students' numerical literacy in chemistry. The PBL model can help students understand problems in everyday life.

In addition to reaction rate material, the PBL model was also implemented in chemical equilibrium material. Chemical equilibrium material is also closely related to numerical literacy. The numerical literacy indicator in chemical equilibrium material is found in the section on calculating the concentration equilibrium constant (Kc). In this case, the data is presented in tables, including pressure equilibrium constants (Kp) and the relationship between Kc and Kp, which uses various basic mathematical numbers and symbols. Based on this, it is known that chemical equilibrium material is closely related to numerical literacy indicators.

One example of a chemical equilibrium question related to numerical literacy is when students are asked to determine the equilibrium constant for a chemical reaction. This question is related to numerical literacy, specifically an indicator of applying numbers or symbols in a mathematical context to solve a problem. Based on the students' answers, they were able to determine the equilibrium constant Kc using the concentration equilibrium constant (Kc) formula by applying mathematical operations, comparing the product concentration with the reactant concentration, each raised to its coefficient (Chang, 2011). Students can also calculate the value of the chemical equilibrium constant in partial pressure (Kp) using the Kp-Kc relationship, which is expressed as $Kp = Kc(RT)^{\Delta n}$. Based on this, students can already use numbers or symbols to calculate the Kp value from the Kc value. Thus, the use of PBL in chemical equilibrium material can help improve students' numerical literacy in chemistry.

The first PBL syntax applied to the material on calculating the concentration equilibrium constant (Kc) is to orient students to the problem. In this syntax, students are guided to recognize contextual problems by using images related to concentration equilibrium, with examples of experimental results presented in tables. The second syntax is organizing students to learn. In this syntax, students learn to determine the concentration equilibrium constant (Kc) through discourse, videos, and examples of questions that contain numbers and basic mathematical symbols. In the third syntax, which guides independent and group investigations, students are trained in numeracy skills by working on exercises presented as numbers and basic mathematical symbols, using tables. This can help improve students' chemical numeracy skills. In the fourth syntax, which involves developing and presenting work results. Students are given exercises using questions presented in the form of numbers and basic mathematical symbols. The fifth syntax is analyzing and evaluating the problem-solving process. In this syntax, students are guided to conclude the material they have learned. During the learning process, students can listen to audio, which supports differentiated learning based on learning styles. Students with a visual learning style can learn by reading the text and watching the videos, while students with an auditory learning style can listen to the text by playing the audio.

In addition to reaction rate and chemical equilibrium, the PBL model was also implemented in salt hydrolysis. Salt hydrolysis is also a chemistry topic that is closely related to numerical literacy. One of the skills required of students in salt hydrolysis is calculating the pH of hydrolyzed salts. In calculating pH, students must be able to apply numbers and mathematical symbols to complete calculations using the appropriate formulas. This aligns with the first numeracy indicator, which is to use various numbers and symbols related to basic mathematics to solve problems in everyday contexts. In addition, in learning about salt hydrolysis, students are also required to analyze the properties of hydrolyzed salts. This aligns with the second and third numerical literacy indicators, namely analyzing information presented in various forms and interpreting the results of the analysis to predict and make decisions (Kemdikbud, 2017).

One example of a question on salt hydrolysis related to numerical literacy requires students to calculate the pH value of a known compound. The question presents the molarity of the salt $(NH_4)_2CO_3$, the Ka value of H_2CO_3, and the Kb value of NH_4OH. To solve this question, students are required to analyze the Ka and Kb values to determine whether the salt (NH_4) $_2CO_3$ is acidic or basic, since the constituent salts are derived from weak acids and weak bases. Salts derived from weak acids and weak bases will ionize in water to form cations and anions. These cations and anions undergo hydrolysis (Ebbing & Gammon, 2009). The pH of the salt is calculated from the Ka and Kb values (Moore, 2011). Based on the student's answer, the Ka value is greater than the Kb value, indicating that the salt is acidic because the hydrolysis of cations is greater than that of anions (Chang, 2011). Students calculated the pH of the salt solution by first determining the [H+] value, then calculating the pH. Referring to the answers, the students were able to analyze and interpret the properties of salt based on the Ka and Kb values, and were able to operate numbers or chemical symbols to calculate the pH value according to the questions presented. This aligns with the three indicators of numerical literacy, which require students to calculate, analyze, and interpret results (Kemdikbud, 2017). Based on this explanation, it can be concluded that the PBL model used in the salt hydrolysis material can help improve students' numerical literacy in chemistry.

Implementing the PBL model in salt hydrolysis learning, following the PBL syntax, can help students solve problems related to mathematical concepts. The first syntax is to orient students to the problem. At this stage, a discourse on everyday life's contextual problems is presented. The problems in the discourse are solved using mathematical calculations to develop students' numerical literacy in chemistry. To understand the problems, students can read the discourse or listen to the audio using the available barcode feature. The second syntax is to organize students to learn. At this stage, images or videos are presented to help students perform mathematical calculations using formulas to solve problems. The third syntax guides individual or group investigations. At this stage, several questions are presented to help students discover and understand concepts. Students can collaborate individually or in groups to solve the questions presented. The questions range from easy to difficult. Students' proficiency in applying numbers and symbols in mathematical calculations is expected to make it easier for them to solve the problems presented in the initial stage. The fourth syntax is the development and presentation of the work's results. The results of the discussion, in the form of working through the questions, are presented to the class to assess students' understanding of the concepts.

The teacher provides clarification when students have misunderstood a concept. The last step is to analyze and evaluate the problem-solving process. The teacher guides students in solving the contextual problems presented at the beginning of the lesson and concludes by reflecting on the learning process. In the PBL-based salt hydrolysis learning, a YouTube video is linked. Students can access the video by scanning the barcode using *their smartphones*. The video provides step-by-step instructions for solving mathematical problems, making it easier for students to apply formulas and perform calculations for salt hydrolysis material. The use of this video can support differentiated learning based on learning styles. Students with visual and auditory learning styles can see and hear the material presented in the video to better understand the lesson's concepts.

To determine the difference in improvement in numerical literacy in chemistry between the experimental and control classes, a hypothesis test was conducted. In selecting the method for the hypothesis test, a normality test was performed. At SMAN X, the experimental class obtained an L-calculated value of 0.08, while the L-table was 0.17. The control class obtained an L-calculated value of 0.11 and an L-table of 0.16. It can be concluded that L-calculated < L-table, so the data are normally distributed. At SMAN Y, the D-calculated value for the experimental and control classes was 0.14, and the D-table value was 0.22. It can be concluded that the D-calculated value is less than the D-table value, indicating that the data is normally distributed. In the experimental class at SMAN Z, the value of L-calculated was 0.12, and the L-table was 0.15. In the control class, L-calculated was 0.09 and L-table was 0.16. It can be concluded that L-calculated < L-table, so the data are normally distributed.

To assess whether the data have homogeneous variance, a homogeneity test is performed. For SMAN X, the F-calculated value is 2.42, and the F-table value is 0.51. F-calculated > F-table, so it can be stated that the data has non-homogeneous variance. For SMAN Y, the F-calculated value was 1.47, and the F-table value was 1.77. F-calculated < F-table, so it can be stated that the data has homogeneous variance. For SMAN Z, the F-calculated value is 1.20, and the F-table value is 1.84. F-calculated < F-table, so it can be stated that the data has a homogeneous variance.

To determine whether the research hypothesis is accepted, a hypothesis test is conducted. The results of the hypothesis test are shown in Table 2.

Table 2. Results of the Two-Way ANOVA Test

School	Source Variation	Sig. (p)	Description
SMAN X	Model	0.002	Significant
	Gender	0.824	Not significant
	Model × Gender	0.026	Significant
SMAN Y	Model	0.006	Significant
	Gender	0.000	Significant
	Model × Gender	0.468	Not Significant
SMAN Z	Model	0.124	Not significant
	Gender	0.508	Not significant
	Model × Gender	0.497	Not significant

Table 2 shows variations in the influence of model, gender, and their interaction in the three schools. At SMAN X, the results show that the model factor is significant. This means there is a difference in achievement between the control and experimental classes, with the experimental class achieving better results. This shows that the PBL model at SMAN X has a real impact on improving students' numerical literacy in chemistry. However, the gender factor is not significant, indicating that numerical literacy in chemistry is not influenced by gender; both male and female students achieve the same results. Although the gender factor does not have a significant effect on numerical literacy in chemistry, there is a significant interaction between gender and model. This shows that the influence of the learning model can differ between genders, even though gender itself does not cause differences in numerical literacy in chemistry.

At SMAN Y, the results show that the model and gender factors have a significant effect on chemistry numerical literacy. This means that using the PBL model improves students' numerical literacy in chemistry at SMAN Y. In addition, the gender factor shows that male and female students obtain different results. However, the absence of a significant interaction indicates that the PBL model remains effective across all genders, with only one gender achieving higher outcomes.

At SMAN Z, neither the model nor gender had a significant effect on chemistry numerical literacy. The use of the PBL model with gender factors did not have a significant effect on numerical literacy in chemistry. This means that the PBL model used produced equivalent results, and the numerical literacy in chemistry results for males and females were similar. The absence of model-by-gender interaction indicates that neither males nor females showed significant differences across the PBL models.

Across the three schools, these findings show that the effect of using the PBL model differs by gender. The results of the two-way ANOVA indicate that the experimental class showed a significant increase in numerical literacy in chemistry compared to the control class in both schools. The gender factor was significant in one school, indicating a difference in numerical literacy in chemistry between male and female students. However, in the other two schools, the gender factor was not significant, indicating no difference between males and females. The interaction between the model and gender was also significant in one school, indicating that the effect of using the PBL model differs by gender in that context. The differences in improvements in numerical literacy in chemistry across schools indicate that the effectiveness of implementing the PBL model does not always yield the same impact in every school context. The variations in improvement may be influenced by several factors, such as differences in student characteristics, teachers' readiness and experience in implementing the PBL model, the school learning environment, and students' initial numerical literacy skills (Nurwidodo et al., 2024; Sari et al., 2024; Nityasanti et al., 2025). Additionally, differences in learning facilities, school academic culture, and the intensity of student engagement in discussion and problem-solving processes can also influence the success of implementing the PBL model in improving chemistry numerical literacy (Gazali et al., 2025). Thus, differences in results across schools indicate that the implementation of learning models should take into account each school's conditions and characteristics to optimally improve numerical literacy in chemistry.

One factor that greatly influenced improvements in students' numerical literacy in chemistry was teachers' pedagogical approach, which fostered active, innovative, enjoyable, and easily absorbed learning (Azizah et al., 2023). The pedagogical aspect lies in the PBL model used. The PBL model is a learning model that can improve students' numerical literacy skills (Tan, 2021). The PBL model is student-centered, thereby increasing student engagement in learning (Almulla, 2020). The application of the PBL model encourages students to collaborate in solving contextual problems. Students can also communicate the solutions to the problems they have collaboratively solved (discussed) with their group (Hidayah, 2021). The PBL model encourages students to collaborate and practice communication skills in line with the learning demands of the Society 5.0 era (Sajidan et al., 2022).

The steps of PBL learning greatly influence students' numerical literacy skills (Sari et al., 2022). In the first syntax, students are oriented towards the problem presented in the form of images and discourse. Students observe the images and read the discourse to understand the contextual problems presented. In addition, there is an audio feature for students who want to listen to the discourse. In the second syntax of the PBL model, the teacher orients to learning. Students collaborate in their groups to gather information and find solutions to the problems presented in the previous stage. In the third syntax of the PBL model, students conduct individual/group investigations. These investigations can take the form of experiments or calculations to solve problems. In the fourth stage of the PBL model, students present their work in the form of reports, videos, or other formats, then share it with the class. The final stage is analyzing and evaluating the problem-solving process. Students find solutions to problems and can draw conclusions based on learning objectives.

The advantage of the PBL model for improving numerical literacy is that the problems presented strongly motivate students to understand the subject matter (Navy & Kaya, 2020). This is evidenced by the results of the PBL model implementation test, in which students increased their chemistry numeracy skills when using the PBL model assisted by electronic chemistry teaching materials (Adhelacahya et al., 2023). In addition, PBL can increase the number of learning activities (Sakir & Kim, 2020). This is because the steps in the PBL model encourage students to actively investigate, collaborate in problem-solving, and be skilled at communicating problem-solving solutions (Magaji, 2021). Another advantage of implementing the PBL model is that it helps students understand problems in everyday life. This is because the problems presented are real and close to students' daily lives. The PBL model also supports real-world learning and motivates students to continue learning.

The use of electronic chemistry teaching materials also supports differentiated learning based on learning styles (Setyaningsih et al., 2023). Electronic teaching materials include technological features such as barcodes or multimedia displays with videos and audio. Students with a visual learning style can learn by reading the text and watching the videos in the electronic teaching materials. Students with an auditory learning style can listen to the discourse via audio and observe the presented videos. Students with a kinesthetic learning style can observe the practicum videos in the electronic teaching materials and apply the knowledge they have gained in independent practicums. The use of digital teaching materials is an innovation to support learning in the era of society 5.0. The integration of digital technology makes learning more engaging by supplementing it with images, animations, and video tutorials, and it is less monotonous than verbal text (Havryliuk et al., 2020). Additionally, the use of digital technology can improve the quality of teachers' learning management (Nurdin et al., 2023). The use of electronic teaching materials, including smartphones as a learning medium, is effective for improving 21st-century skills (Mufit et al., 2023).

The findings of this study indicate an improvement in numerical literacy in chemistry skills through the implementation of the PBL model, consistent with previous studies showing improvements in students' science literacy skills (Paristiowati et al., 2019) and science process skills. In this research, the PBL model has been proven effective not only in developing science literacy but also in improving students' 21st-century science learning skills (Aripin et al., 2025). Other studies also report that implementing the PBL model can improve students' achievement in chemistry (Aidoo et al., 2016), enhance critical thinking skills (Wulandari & Supiah, 2023), and foster scientific attitudes during the learning process (Anazifa & Djukri, 2017). Other findings also indicate that implementing the PBL model can improve students' problem-solving skills (Gultom & Rohaeti, 2024), creative thinking skills (Iftitah et al., 2023), and creative actions (Wahyudiati, 2022). Other studies show that the PBL model positively affects students' digital literacy (Yustina et al., 2022). These findings are consistent with the results of this study. This is because the learning steps in the PBL model encourage students to be active learners, helping them develop their thinking skills. The steps in the PBL model include scientific activities such as identifying problems, conducting literature reviews, conducting experiments, and analyzing and communicating experimental data, to develop students' scientific attitudes and literacy skills. Thinking and literacy skills are important for 21st-century learning.

The results of the study show that in two schools, gender did not have a significant effect on improving chemistry numerical literacy. This finding indicates that the PBL model can create an inclusive learning environment, where opportunities for critical thinking, discussion, and problem-solving are provided equally, without distinction by gender. Equality can occur because the PBL model emphasizes group work, open communication, and students' active involvement in solving problems. In this context, teachers play an important role in ensuring a balanced distribution of group roles and encouraging equal participation between male and female students. This aligns with previous research findings, which show that gender has no significant influence on students' understanding of problems, problem-solving abilities, or curiosity (Yusuf, 2023). This reinforces the results of this study, which show that both male and female students have balanced curiosity, problem understanding, and problem-solving abilities when involved in problem-based learning. In other words, the PBL model provides equal space for both genders to develop through critical thinking activities.

The results of this study show that students' numerical literacy in chemistry skills improved significantly when the PBL model was applied. These results have implications for educators to apply the PBL model in chemistry learning. The use of this model can facilitate heterogeneous students' learning by allowing them to learn according to their learning styles. Thus, implementing the PBL model can facilitate differentiated learning. In addition, continuous efforts are needed to implement the PBL model effectively in a heterogeneous classroom environment.

The limitations of this study regarding the implementation of the PBL model include variability in students' abilities in chemistry, which may affect the study's results. Although purposive sampling was used to select classes based on academic characteristics, variations in individual abilities within each class could not be fully controlled. These differences in initial abilities can affect the dynamics of group discussions and the effectiveness of PBL implementation during the learning process. Furthermore, the research was limited to three chemistry topics: reaction rates, chemical equilibrium, and salt hydrolysis. Moreover, the use of electronic teaching materials accessible via smartphones has limitations when answering essay questions on mathematical calculations in chemistry, so these questions were answered by hand. Nevertheless, this study provides empirical support for integrating PBL, digital technology, and gender, and contributes to SDG-4, which is to improve students' numerical literacy in chemistry.

Further research could be conducted to implement the PBL model in other chemistry materials to improve students' numerical literacy skills in high school. In addition, the PBL model can be implemented in different contexts to provide a comprehensive understanding of PBL in learning. Furthermore, the study's sample size can be expanded to achieve higher accuracy in the research results.

CONCLUSION

This study demonstrates that implementing the PBL model effectively improves students' chemical numeracy skills. This is evidenced by the N-Gain scores in the experimental class, which were generally higher than those in the control class, indicating that problem-based learning encourages students to develop data analysis skills, use mathematical symbols, and interpret calculation results when solving quantitative chemistry problems. Furthermore, the results indicate that the influence of gender on chemical numeracy skills in PBL implementation does not follow a consistent pattern across all schools. In one school, the gender effect was significant, whereas in another it was not; thus, overall, the chemical numeracy skills of male and female students are relatively comparable. This finding confirms that the implementation of the instructional model has a greater influence on improvements in chemical numeracy than gender factors do. Thus, this study contributes to strengthening the empirical evidence on the effectiveness of PBL in improving chemical numeracy skills while demonstrating that the model can be implemented inclusively, with no significant gender differences in achievement. Further research is recommended to involve a broader sample and examine other factors that may influence students' chemical numeracy skills.

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REFERENCES

Adhelacahya, K., Sukarmin, S., & Sarwanto, S. (2023). The impact of problem-based learning electronics module integrated with STEM on students' critical thinking skills. *Jurnal Penelitian Pendidikan IPA, 9*(7), 4869-4878.

Abusamra, A. (2024). University EFL students' perceptions of using second-generation web 2.0 tools in developing English language skills. *Journal of Educational Horizons, 43*(2), 452–458.

Aguillon, S. M., Siegmund, G. F., Petipas, R. H., Drake, A. G., Cotner, S., & Ballen, C. J. (2020). Gender differences in student participation in an active-learning classroom. *CBE—Life Sciences Education, 19*(2), ar12.

Aidoo, B., Boateng, S. K., Kissi, P. S., & Ofori, I. (2016). Effect of Problem-Based Learning on Students' Achievement in Chemistry. *Journal of Education and Practice, 7*(33), 103-108.

Aliyyah, R. R., Fauziah, S. P., & Marini, A. (2024). Digital Library: Lecturers' Perceptions of Facilitating Learning Resources in the Industrial Era 4.0. *Journal of Education and E-learning Research*, *11*(1), 203-210.

Almagribi, A. Z., Al-Qahtani, S. M., Assiri, A. M., & Mehdar, K. M. (2024). Perceptions of medical students at Najran University on the effectiveness of problem-based learning and team-based learning. *BMC Medical Education, 24*(1).

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach to engage students in learning. *Sage Open, 10*(3), 2158244020938702.

Altindis, N., Bowe, K. A., Couch, B., Bauer, C. F., & Aikens, M. L. (2024). Exploring the role of disciplinary knowledge in students' covariational reasoning during graphical interpretation. *International Journal of STEM Education, 11*(1), 32.

Anazifa, R. D., & Djukri, D. (2017). Project-based learning and problem-based learning: Are they effective to improve student's thinking skills?. *Jurnal Pendidikan IPA Indonesia, 6*(2), 346-355.

Anwar, L., Alimin, M., Copriady, J., & Rery, R. U. (2024). Pre-Service chemistry teachers' attitude of socio-scientific issues and characters as citizens. *Jurnal Pendidikan IPA Indonesia*, *13*(3).

Aripin, N., Mufit, F., Lufri, L., Andromeda, A., & Festiyed, F. (2025). The role of problem-based learning in developing science literacy and 21st-century skills in high school students: A meta-analysis. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1).

Asda, V. D., Andromeda, A., Hardeli, H., & Yerimadesi, Y. (2025, July). The Effect of Buffer Solution Students' Worksheet Based on Problem-Based Learning with Ethnochemistry Nuances Integrated Technology to Improve Students' Science Literacy Ability. In *2nd International Conference on Sciences, Mathematics, and Education 2023 (ICOSMED 2023)* (pp. 557-564). Atlantis Press.

Awami, F., Yuhana, Y., & Nindiasari, H. (2022). Meningkatkkan kemampuan literasi numerasi dengan model problem-based learning (PBL) ditinjau dari self-confidence siswa SMK. *MENDIDIK: Jurnal Kajian Pendidikan dan Pengajaran*, *8*(2), 231-243.

A'yuni, Q., & Ardhana, I. A. (2024). Pengembangan media pembelajaran berbasis website Google Sites menggunakan pendekatan saintifik untuk melatih numerasi siswa pada materi hukum dasar kimia. *Chem. Educ. Rev. CER*, *8*(2), 54-62.

Azizah, S. N., Mumfaza, R., Amala, R. A., Roisah, R., Agustin, V. H., Nurmelinia, N., ... & Hidayah, N. (2023). Improvement of Literacy, Numeracy and Life Skills of "Sanggar Belajar" Students in Malaysia. *Jurnal Pengabdian Masyarakat Nusantara (JPMN), 3*(1), 71-80.

Bakhsh, K., Hafeez, M., Shahzad, S., Naureen, B., & Faisal Farid, M. (2022). Effectiveness of digital game based learning strategy in Higher Educational Perspectives. *Journal of Education and E-learning Research*, *9*(4), 258-268.

Bappenas. (2024). *Metadata Metadata indicators for 2024 social development: implementation of sustainable development goals (SDGs). Deputy* for Maritime Affairs and Natural Resources, Ministry of National Development Planning/National Development Planning Agency.

Cahyana, U., Luhukay, J. R., Lestari, I., Irwanto, I., & Suroso, J. S. (2023). Improving Students' Literacy and Numeracy Using Mobile Game-Based Learning with Augmented Reality in Chemistry and Biology. *International Journal of Interactive Mobile Technologies, 17*(16).

Chang, Y. H., Yan, Y. C., & Lu, Y. T. (2022). Effects of combining different collaborative learning strategies with problem-based learning in a flipped classroom on program language learning. *Sustainability, 14*(9), 5282.

Chi, M., Zheng, C., & He, P. (2024). Assessing high school students' chemical thinking using an essential questions-perspective framework. *Chemistry Education Research and Practice, 25*(4), 1143-1158.

Choo, S. Y., & Taha, H. (2023). Embracing Gen-Z's learning styles with a mobile enthalpy game application (MEGA) for thermochemical equations. *Jurnal Cakrawala Pendidikan, 42*(1), 64–76.

Fausan, M. M., Susilo, H., Gofur, A., Sueb, S., & Yusop, F. D. (2021). The scientific literacy performance of gifted young scientist candidates in the digital age. *Jurnal Cakrawala Pendidikan*, *40*(2), 467-498.

Fitrawati, F., Syarif, H., Zaim, M., & Perrodin, D. D. (2023). The perceptions of tertiary students and lecturers regarding CLIL-based critical reading material employing interactive multimedia. *Indonesian Journal of Applied Linguistics, 12*(3), 598–611.

Fitriyana, N., Wiyarsi, A., Ikhsan, J., & Sugiyarto, K. H. (2020). Android-Based-Game And Blended Learning In Chemistry: Effect On Students' Self-Efficacy And Achievement. *Jurnal Cakrawala Pendidikan, 39*(3), 507–521.

Fongkanta, P., & Buakanok, F. S. (2024). Development novice teachers' higher-order thinking skills through online problem-based learning platform: A mixed methods experimental research. *Jurnal Cakrawala Pendidikan*, *43*(3), 756-764.

Fraenkel, J. R., & Wallen, N. E. (1990). *How to design and evaluate research in education*. Order Department, McGraw Hill Publishing Co., Princeton Rd., Hightstown, NJ 08520.

Gazali, F., Rahayu, S., Munzil, M., Wonorahardjo, S., & Alam, M. D. (2025). Systematic literature review on the application of the problem-based learning model in chemistry education. *Ecletica Química, 50*, e1598.

Gultom, H., & Rohaeti, E. (2024). The Effectiveness of the Ethnochemistry-based Problem Based Learning Model on Students' Problem-Solving Ability in Chemistry Learning: A Meta-analysis Study in 2021-2024. *Journal of Science Education Research*, *10*(7), 508–514.

Guo, J., Marsh, H. W., Parker, P. D., & Hu, X. (2024). Cross-cultural patterns of gender differences in STEM: Gender stratification, gender equality, and gender-equality paradoxes. *Educational Psychology Review, 36*, 37.

Havryliuk, N., Osaulchyk, O., Dovhan, L., & Bondar, N. (2020, May). Implementation of E-learning as an Integral Part of the Educational Process. In *Society. Integration. Education. Proceedings of the international scientific conference* (Vol. 4, pp. 449-459).

Hidayah, R., Fajaroh, F., Parlan, P., & Dasna, I. W. (2021). Collaborative problem based learning model for creative thinking ability. *Journal of Asian Multicultural Research for Educational Study*, *2*(2), 24-30.

Hidayatullah, & Setiawan, B. (2024). Empowering students' collaborative skills sustainability by utilizing problem-based learning as an instructional strategy in online learning. *Cogent Education, 11*(1), 2362006.

Iftitah, N., Arsyad, M., & Palloan, P. (2023). The effect of problem-based learning model and self-efficacy towards creative thinking ability of class xi mipa students at sma negeri 11 takalar. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10808-10815.

Imala, Z., Sunaengsih, C., & Syahid, A. A. (2024). The Effect of The Problem-Based Learning Model on the Numerical Literacy Ability of Elementary School Students. *Jurnal Cakrawala Pendas*, *10*(3), 512-522.

Islamiati, E. F., & Redhana, I. W. (2025, July). The use of e-module in chemistry learning: A literature review. In *AIP Conference Proceedings* (Vol. 3206, No. 1, p. 070010). AIP Publishing LLC.

Jansson, S., Söderström, H., Andersson, P. L., & Nording, M. L. (2015). Implementation of Problem-Based Learning in Environmental Chemistry. *Journal of Chemical Education, 92*(12), 2080–2086.

Jasrial, J., Saputra, A., & Rifma, R. (2023). Improving learning outcomes: The effectiveness of e-book reading literacy based in learning management psychology. Jurnal *Cakrawala Pendidikan, 42*(3), 631–641.

Kawuryan, S. P., Sayuti, S. A., & Aman, A. (2021). Critical thinking among fourth grade elementary students: a gender perspective. *Jurnal Cakrawala Pendidikan, 41*(1), 211–224.

Khaeruddin, K., Wahyuni, A. S. A., & Kijkuakul, S. (2025). Digitally Integrated Project-Based Contextual Physics Resources to Enhance Students' Critical Thinking Skills to Support SDG-4. *Jurnal Pendidikan IPA Indonesia*, *14*(4).

Kristiantari, M. G. R., Widiana, I. W., Tristiantari, N. K. D., & Rediani, N. N. (2022). Impact of Prezi Media-Assisted Problem-Based Learning on Scientific Literacy and Independence of Elementary School Students. *Journal of Education and E-Learning Research, 9*(3), 184–191.

Kucuk, S., & Sisman, B. (2020). Students' attitudes towards robotics and STEM: Differences based on gender and robotics experience. International *Journal of Child-Computer Interaction, 23*, 100167.

Kumalasari, D., Purwanta, H., & Aw, S. (2024). Comparative analysis of Generation Z's digital history literacy in history education majors on Java Island: A study of history digital literacy. *Journal of Education and E-Learning Research, 11*(1), 90–96.

Kuncoro, T., Ichwanto, M. A., & Dwiyanto, F. A. (2025). Immersive learning through virtual reality for civil engineering education. *Jurnal Cakrawala Pendidikan, 44*(1), 92–101.

Lubna, L., Suhirman, S., & Prayogi, S. (2023). Evaluation of STEM students' critical thinking in terms of cognitive style through problem-based distance learning. *Journal of Education and E-Learning Research, 10*(3), 557–568.

Lukman, L. (2023). Student's Literacy and Numeracy Skills in Ombok Island, West Nusa Tenggara : Baseline Survey Innovation Based Gender Equality, Disability, and Social. *Journal of Education: Journal of Research and Literature Review in the Field of Education, Teaching and Learning*, *9*(2), 444–455.

Magaji, A. (2021). Promoting problem-solving skills among secondary science students through problem-based learning. *International Journal of Instruction, 14*(4), 549-566.

Mangubat, F. M., & Mangubat Jr, F. N. (2025). Non-STEM Students in Undergraduate Science: A Global Bibliometric Review Toward Sustainable Development Goal 4 (2017–2025). *Indonesian Journal of Science Education*, *14*(4).

Manurung, S. R., & Panggabean, D. D. (2020). Improving Students'thinking Ability in Physics Using Interactive Multimedia Based Problem Solving. *Jurnal Cakrawala Pendidikan*, *39*(2), 460-470.

Marsila, N. (2025). Development of an Acid-Base E-Module Based on Guided Discovery Learning with Ethnoscience Content to Improve Literacy and Numeracy. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 1125-1135.

Martiana, T., Wardani, S., & Nuswowati, M. (2025). Development of Problem-Based Learning (PBL) Chemistry Modules to Provide Students' Numeracy-Literacy Skills in Materials of Colligative Property Solutions. *Chemistry in Education*, *14*(2), 42-52.

Maulidia, L., Nafaridah, T., Ratumbuysang, M. F. N. G., & Sari, E. M. K. (2023). Analisis keterampilan abad ke 21 melalui implementasi kurikulum merdeka belajar di sma negeri 2 banjarmasin: The analysis of 21st century skills through the implementation of the independent learning curriculum at sma negeri 2 banjarmasin. *Prospek*, *2*(2), 127-133.

Memon, M.A., Thurasamy, R., Ting, H., & Cheah, J. (2025). Purposive Sampling: A Review and Guidelines for Quantitative Research. *Journal of Applied Structural Equation Modeling*.

Moliner, L., Lorenzo-Valentin, G., & Alegre, F. (2021). E-Learning during the Covid-19 Pandemic in Spain: A Case Study with High School Mathematics Students. *Journal of Education and E-Learning Research, 8*(2), 179–184.

Mufit, F., Hendriyani, Y., Usmeldi, M. D., & Tanjung, M. R. (2023). The effectiveness of smartphone-based interactive multimedia integrated cognitive conflict models to improve 21st-century skills. *International Journal of Information and Education Technology*, *13*(11), 1793-1801.

Navy, S. L., & Kaya, F. (2020). PBL as a pedagogical approach for integrated STEM: Evidence from prospective teachers. *School Science and Mathematics, 120*(5), 285-296.

Nggawu, L. O. (2024). The influence of gender and self-efficacy on the English writing ability of central Indonesian students. *Indonesian Journal of Applied Linguistics, 14*(1), 195–205.

Ningrum, S., & Crosthwaite, P. (2020). Gender- -preferential language use in L1 and L2 argumentative essays? Evidence against lists of "gendered" language features. *Indonesian Journal of Applied Linguistics, 10*(1), 226–241.

Nityasanti, N., Laila, A., Saida, A., Baharudin, B., & Yasin, M. H. M. (2025). 21st century learning: A research analysis of numeracy literacy trends among students. *IJORER: International Journal of Recent Educational Research, 6*(1), 264-277.

Nur, D., Sumarwati Sumarwati, & Raheni Suhita. (2024). Indonesian Junior High School Students' Perceptions of Using Digital Storytelling Media in Learning to Write Fantasy Stories. *International Journal of Learning Teaching and Educational Research, 23*(10), 564–582.

Nurdin, D., Marnita, M., & Ghani, M. F. B. A. (2023). Digital Transformation To Improve Teachers' Learning Management and Students' Science Life Skills. *Indonesian Journal of Science Education*, *12*(3), 329–342.

Nurwidodo, N., Wahyuni, S., Hindun, I., & Fauziah, N. (2024). The effectiveness of problem-based learning in improving creative thinking skills, collaborative skills and environmental literacy of Muhammadiyah secondary school students. *Research and Development in Education (RaDEn)*, *4*(1), 49-66.

Odom, S., Boso, H., Brownell, S., Cotner, S., Eddy, S., Fagbodun, S., Ballen, C. J. (2021). Metaanalysis of gender performance gaps in undergraduate natural science courses. *CBE—Life Sciences Education, 20*(3), ar40.

OECD. (2023). *PISA 2022 Results The State of Learning and Equity in Education*. Paris: OECD Publishing.

Oladejo, A. I., Nwaboku, N. C., Okebukola, P. A., & Ademola, I. A. (2023). Gender difference in students' performance in chemistry–can computer simulation bridge the gap?. *Research in Science & Technological Education*, *41*(3), 1031-1050.

Paristiowati, M., Cahyana, U., & Bulan, B. I. S. (2019). Implementation of problem-based learning–flipped classroom model in chemistry and its effect on scientific literacy. *Universal Journal of Educational Research, 7*(9).

Perdana, R., Jumadi, J., Rosana, D., & Riwayani, R. (2020). The Online Laboratory Simulation With Concept Mapping And Problem Based Learning (Ols-Cmpbl): Is It Effective In Improving Students' Digital Literacy Skills?. *Jurnal Cakrawala Pendidikan, 39*(2), 382–394.

Pertiwi, N. Y., & Ardhana, I. A. (2025). Analysis of numeracy literacy ability of 11th grade students on reaction rate material at SMAN 1 Grogol. *International Journal of Chemistry Education Research, 9*(2), 175-186.

Pineda, V., Gallegos, A., Valencia, J., Valencia-Arias, A., Benitez, A. O. M., & Cifuentes, B. J. O. (2025). Identifying Trends in the Study of Gender in Science, Technology, Engineering, and Mathematics (STEM) Programs. *Jurnal Pendidikan IPA Indonesia*, *14*(2).

Pusmenjar. (2020). *AKM Question Development Design.* Jakarta: Ministry of Education and Culture, Development and Book Publishing.

Qondias, D., Lasmawan, W., Dantes, N., & Arnyana, I. B. P. (2022). Effectiveness of Multicultural Problem-Based Learning Models in Improving Social Attitudes and Critical Thinking Skills of Elementary School Students in Thematic Instruction. *Journal of Education and E-Learning Research, 9*(2), 62–70.

Rachmadtullah, R., Setiawan, B., Wasesa, A. J. A., Wicaksono, J. W., & Rasmitadila. (2023). The utilization of metaverse technology applications based on science, technology, engineering and mathematics (Meta-STEM) to improve critical thinking skills. *Journal of Education and E-Learning Research, 10*(4), 778–784.

Rangkuti, A. N., Sitompul, L., Amran, A., Lubis, M. S., Hoiriyah, D., Sari, L. N. I., ... & Rambe, S. (2024). The Influence of Scientific-Based Numeracy Literacy Teaching Materials on Students' Motivation and Higher Order Thinking Abilities. *Jurnal Pendidikan IPA Indonesia*, *13*(4).

Rashid, S., & Howard, J. (2023). Blogging with smartphones for independent writing practice beyond the EFL classroom. *Indonesian Journal of Applied Linguistics, 12*(3), 790–801.

Razak, H. M., Razak, N. A., & Krish, P. (2022). Enhancing students' digital literacy at EFL classroom: Strategies of teachers and school administrators. *Jurnal Cakrawala Pendidikan*, *41*(3), 653-664.

Rudolphi-Solero, T., Bajos-Ariza, F., Lorenzo-Álvarez, R., Domínguez-Pinos, D., Ruiz-Gómez, M. J., & Sendra-Portero, F. (2025). Problem-based learning in radiology achieves similar results in classroom and metaverse settings. *Insights into Imaging, 16*(1).

Rusydiyah, E. F., Asrohah, H., Basyir, K., Rahman, M. R., & Usagawa, T. (2024). Structural model of digital transformation readiness of Indonesian rural and urban science teachers. *Jurnal Pendidikan IPA Indonesia*, *13*(2).

Sajidan, S., Suranto, S., Atmojo, I. R. W., Saputri, D. Y., & Etviana, R. (2022). Problem-based learning-collaboration (PBL-C) model in elementary school science learning in the industrial revolution era 4.0 and Indonesia society 5.0. *Jurnal Pendidikan IPA Indonesia, 11*(3), 477-488.

Sakir, N. A. I., & Kim, J. G. (2020). Enhancing students' learning activity and outcomes via implementation of problem-based learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(12), em1925.

Salfina, S., Nurmaliah, C., Pada, A. U. T., Hasanuddin, H., & Abdullah, A. (2021). Application of problem based learning model in integrated media animation to improve students' science process skills. *Jurnal Penelitian Pendidikan IPA*, *7*, 266-271.

Salim, F., Purwanto, A., & Lestari, I. (2024). Improving Students' Science Problem Solving Ability through the Implementation of Problem Based Learning Models Assisted by Animation Media. *International Journal of Elementary Education*, *8*(2), 269-278.

Sari, M. E., Ermalinda, E., Nurhandayani, N., & Mabruria, A. (2024). Problem-based learning in mathematics education: Analysis of teachers' challenges and implementation solutions. *Lentera Sriwijaya: Jurnal Ilmiah Pendidikan Matematika, 6*(2), 54–63.

Sari, R. M. M., Priatna, N., & Juandi, D. (2022). Implementing Project-Based Blended Learning Model Using Cognitive Conflict Strategy to Enhance Students' Mathematical Spatial Literacy. *European Journal of Educational Research, 11*(4), 2031-2041.

Setyaningsih, A., Maryati, M., Wilujeng, I., & Ilma, A. Z. (2023). Electronic Science Module in the Merdeka Curriculum: Teacher and Student Perspectives. *Jurnal Penelitian Pendidikan Ipa*, *9*(SpecialIssue), 1172-1178.

Shaber, N., Shah, S. K., Imran, M., & Almusharraf, N. (2025). Exploring the relationship between critical thinking and creativity in university students: gender differences and the assessment of skills. *Education Sciences*, *15*(4), 464.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard educational review*, *78*(1), 40-59.

Simbolon, N. E., & Febrianti, Y. (2020). The selection of learning materials from YouTube resources for a Maritime English Course. *Indonesian Journal of Applied Linguistics, 10*(2), 460–470.

Sucipto, S., Hidayat, Y., Hambali, B., Gumilar, A., & Nur, L. (2023). Exploring the influence of gender and tactical learning approaches on students' enjoyment levels in physical education. *Jurnal Cakrawala Pendidikan*, *42*(3), 719-732.

Suharno, S., & Setyarini, S. (2021). Promoting Efl Junior Secondary Students'critical Thinking Skills Through Analogical Reasoning in Narrative Text. *Indonesian Journal of Applied Linguistics*, *11*(1), 211-220.

Sultan, S., Rapi, M., Mayong, M., & Suardi, S. (2020). Textbook Discourse Readability: Gender, Reading Interest, And Socio-Economic Status of Students with Poor Reading Ability. J*urnal Cakrawala Pendidikan, 39*(3), 583–596.

Sumardi, S., & Muamaroh, M. (2020). Edmodo Impacts: Mediating Digital Class and Assessment in English Language Teaching. *Jurnal Cakrawala Pendidikan, 39*(2), 319–331.

Suprawata, I. G., & Riastini, P. N. (2022). Gender and Educational Level: Analysis of Elementary School Teacher Numerical Skills. *Jurnal Ilmiah Sekolah Dasar*, *6*(2), 236–243.

Suresman, E., Febrianti, F. A., & Dallyono, R. (2023). Implementation of i-Spring Suite to improve students' learning for critical thinking skills in natural science. *Cakrawala Pendidikan*, *42*(2), 433-446.

Suyato, S., Hidayah, Y., Septiningrum, L., & Arpannudin, I. (2024). Application of the collaborative learning model to improve 21st-century civic skills. *Journal of Education and E-Learning Research, 11*(3), 456–463.

Tan, O. S. (2021). *Problem-based learning innovation: Using problems to power learning in the*^{21st} *century*. Gale Cengage Learning.

Wahyudi, W., Setiawan, A., Suhandi, A., Samsudin, A., & Kamin, Y. B. (2024). Assessing Prospective Physics Teachers' Inquiry Skills in Post-Pandemic: Rasch Analysis. *Jurnal Pendidikan IPA Indonesia*, *13*(3).

Wahyudiati, D. (2022). Critical thinking skills and scientific attitudes of pre-service chemistry teachers through the implementation of problem-based learning model. J*urnal Penelitian Pendidikan IPA, 8*(1), 216-221.

Wang, N., Tan, A. L., Zhou, X., Liu, K., Zeng, F., & Xiang, J. (2023). Gender differences in high school students' interest in STEM careers: A multi-group comparison based on structural equation model. *International Journal of STEM Education, 10*(1), 59.

Wulandari, R., & Supiah YL, I. (2023). Effectiveness of Problem-Based Learning Chemistry Modules and Their Impact on Students' Critical Thinking Abilities. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 163-170.

Yermekbayeva, G., Kuzembayeva, G., Maydangalieva, Z., & Spulber, D. (2024). Effects of interactive learning module technology on Kazakh as a second language learners' achievement and communication skills. *Journal of Education and E-Learning Research, 11*(3), 519–526.

Yustina, Y., Mahadi, I., Daryanes, F., Alimin, E., & Nengsih, B. (2022). The effect of problem-based learning through blended learning on digital literacy of eleventh-grade students on excretory system material. *Jurnal Pendidikan IPA Indonesia*, *11*(4), 567-577.

Yusuf, Y. (2023). Gender in Problem Based Learning: Curiosity Analysis, Problem Understanding, and Problem Solving Ability. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *11*(2), 485-498.

Zainil, M., Kenedi, A. K., Indrawati, T., & Handrianto, C. (2023). The Influence of a STEM-Based Digital Classroom Learning Model and High-Order Thinking Skills on the 21st-Century Skills of Elementary School Students in Indonesia. *Journal of Education and E-Learning Research*, *10*(1), 29-35.

Zigh, E., Abdalli, R. H., & Kouninef, B. (2022). Impact of E-Learning on INTTIC Students during the COVID-19. *Journal of Education and E-Learning Research*, *9*(1), 28-37.