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Systematic Literature Review: Analysis the Implementation of the 5E Learning Cycle in Learning Chemistry

Siska Juita Berlian Putri Gea[1], Wiji[1*], Tuszie Widhiyanti[1]

[1]Master of Chemistry Education, FPMIPA, Universitas Pendidikan Indonesia, Bandung, Indonesia.

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Corresponding Author:
Wiji Wiji
maswiji@upi.edu

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Abstract: This study aims to analyze the implementation of the 5E (Engage, Explore, Explain, Elaborate, and Evaluate) learning cycle in chemistry learning, to analyze multiple representations (macroscopic, submicroscopic, and symbolic) as characteristics of chemistry, and to identify learning outcomes. This study was conducted using a Systematic Literature Review (SLR) in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A total of 38 articles from Google Scholar from 2020 to 2026 were analyzed based on the determined inclusion criteria. The results show that the implementation of the 5E learning cycle in chemistry learning has been widely applied across various topics in chemistry. Although various levels of representation have been used, the relationship between macroscopic, submicroscopic, and symbolic representations is still limited in these articles. Findings also indicate that cognitive learning outcomes are the most frequently reported, particularly conceptual understanding and academic achievement. Several studies also explored affective outcomes and other skills, which indicate a more diverse range of learning outcomes. Overall, the evidence suggests that the 5E learning cycle contributes positively to chemistry learning.

Keywords: Chemistry education; Learning outcomes; Multiple representation; 5E learning cycle

Introduction

Chemistry education has a strategic role in developing scientific thinking skills, conceptual understanding, and 21st-century skills that students need to face global challenges (Ambarwati et al., 2021; Darwis, Fitriani, & Styariyani, 2020). However, chemistry learning has complex characteristics because chemical concepts are not only related to phenomena that can be observed at the macroscopic level, but also need to be understood through submicroscopic and symbolic representations. Johnstone explained that these three levels of representation need to be interconnected so that students can build meaningful chemical understanding (Petillion & McNeil, 2020). These characteristics of chemistry learning mean that many students struggle to develop a comprehensive conceptual understanding. Therefore, a learning approach is needed that can facilitate students' active engagement while supporting the process of knowledge construction

One approach widely used for this purpose is the 5E learning cycle, which involves systematic and student-centered learning. The 5E learning cycle was developed by Roger Bybee and his colleagues in the late 1980s as a constructivist-based learning approach designed to enhance students' conceptual understanding in science learning (Bybee et al., 2006).

The 5E learning cycle provides the view that students can construct their own knowledge through direct experience and active interaction with the learning environment (Savarimuthu & Susairaj, 2022).(Ha, Chung, Hanh, & Hai, 2023)The 5E learning cycle includes five phases: Engage, Explore, Explain, Elaborate, and Evaluate. In the Engage phase, students are encouraged to develop curiosity about the material

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being studied. In the Explore phase, students are given the opportunity to discover concepts through investigative activities. The Explain phase helps students articulate their understanding, while the Elaborate phase expands the application of concepts in new contexts. Finally, the Evaluate phase ensures understanding through continuous reflection and assessment (Boakye & Nabie, 2022; Chen, Chen, & Li, 2022; Eroğlu & Bektaş, 2022)

Several previous systematic reviews have provided an important foundation for developing research on the 5E learning cycle. Ünlü & Dökme (2022) reviewed empirical research on the 5E model in science education and found that most research still focuses on lower-level learning outcomes, such as knowledge and conceptual understanding, while higher-order thinking skills, 21st-century skills, and affective dimensions such as attitude, motivation, curiosity, and efficacy have not been extensively mapped in specific field contexts. Furthermore, in an article by Polanin et al. (2024) through a systematic review and meta-analysis, it was shown that the 5E learning model and its variations have a positive influence on science, mathematics, and student motivation learning outcomes; however, these studies were still limited to STEM and science in general, so they did not specifically map the implementation of 5E in chemistry education. Joswick & Hulings (2024) also showed that the BSCS 5E model is generally more effective than traditional learning, but empirical evidence is still concentrated on science education in general, especially biology, while studies in the chemistry context are still relatively limited. On the other hand, Jegstad (2024) specifically reviewed inquiry-based chemistry education and showed that research on inquiry-based chemistry learning tends to focus on the conceptual and affective domains, but the 5E model appears as only one small part of the various inquiry approaches studied.

Although previous studies have demonstrated the effectiveness of the 5E learning model in science education, its implementation in chemistry education still requires a more focused synthesis. Existing reviews have mostly discussed the 5E model in general science contexts and have not specifically mapped how it is applied across chemistry topics, how it relates to students' learning outcomes and affective dimensions, or how it supports the interconnection of macroscopic, submicroscopic, and symbolic representations. Therefore, this study systematically reviews the literature to identify implementation approaches of the 5E learning cycle, examine how multiple representations are incorporated, and synthesize the learning outcomes reported in chemistry education research. This study is expected to provide a more specific synthesis of implementation patterns and future directions for developing 5E-based chemistry learning that is more adaptive, representationally oriented, and relevant to twenty-first-century learning.

Method

This study used a Systematic Literature Review (SLR) approach, referring to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. PRISMA was first developed by (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009) as a guideline for reporting systematic reviews and meta-analyses, and was later updated to PRISMA 2020 by Page et al. (2021). These guidelines are used to ensure that the process of identifying, screening, assessing eligibility, and including articles is carried out systematically and transparently.

The articles in this study were obtained through a literature search on Google Scholar. This database was chosen because it has a broad source coverage and it is able to search scientific articles from various journals, publishers, and academic repositories. The article search was limited to the period 2020–2026. This timeframe was chosen to obtain an overview of the latest research on the application of the 5E learning model in chemistry education, particularly that which has developed in recent years.

The search used the keywords "5E learning cycle" OR "5E model" AND "Science Education" OR "Chemistry Education" which were combined using Boolean operators. Articles retrieved from the search were screened according to predefined inclusion and exclusion criteria. The inclusion criteria in this SLR include scientific journal articles that are peer-reviewed, published from 2020 to 2026, written in Indonesian or English, and related to chemistry learning. In addition, selected articles must be available in full text form to allow for comprehensive analysis. The exclusion criteria included articles that did not go through a peer-reviewed process, were published outside the 2020–2026 period, were not in Indonesian or English, were not related to chemistry learning, and were not available in full text. Articles in the form of opinions, editorials, book chapters, theses, dissertations, activity reports, conceptual articles without empirical data, and articles that only discuss the 5E model outside the context of chemistry were also excluded from this study. The results of article screening based on the inclusion and exclusion criteria in the PRISMA flow are shown in Figure 1. The scope of chemistry learning in this study is not limited to topics taught at the school level but also includes chemistry learning at the university level and various relevant contexts of applied chemistry.

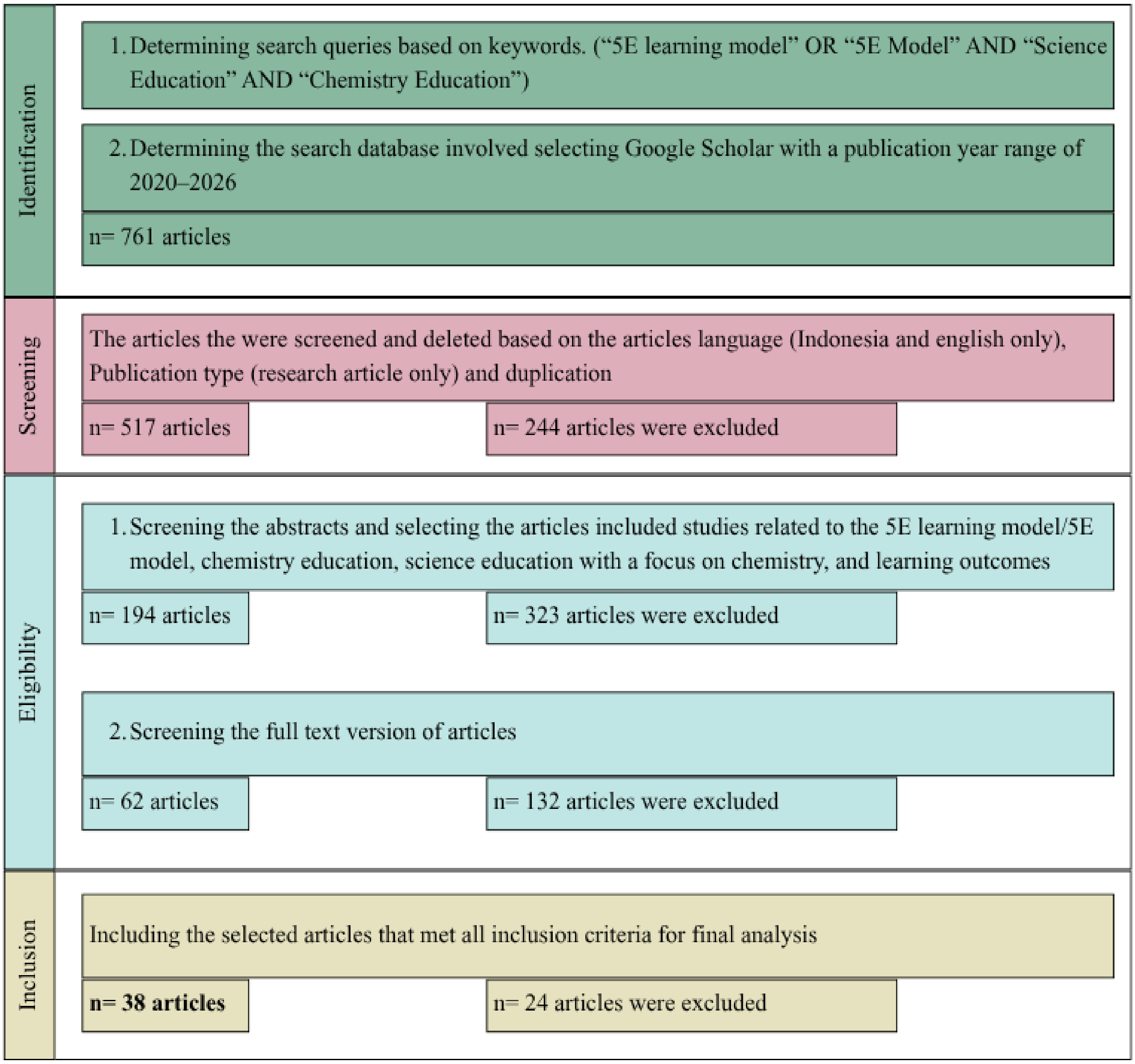

Figure 1. Table Of PRISMA

Result and Discussion

As shown in **Table 1**, the reviewed studies reveal the flexibility of the 5E learning cycle, which can be adapted to various learning situations and combined with various pedagogical approaches to support a variety of learning objectives.

Analysis of the Implementation of the 5E Learning Cycle in the Chemistry Learning Context

An analysis of articles that use the 5E learning cycle shows that this model is applied to a wide range of chemistry topics. This variety ranges from basic theoretical concepts to applied concepts **(Table 1).** The implementation of each 5E phase shows variations adjusted to the characteristics of the chemistry material being studied. The 5E learning cycle is widely used as an alternative learning approach that is considered capable of helping students understand chemical concepts more effective than conventional learning (Ali, Ullah, Ahmad, & Ahmed, 2025; Kibor, Ndeke, & Wambugu, 2023; Nursafitri, Santoso, & Sumari, 2021; Tahira, Azhar, & Bajwa, 2024).

Table 1. Results of a Literature Review on the Implementation of the 5E Learning Cycle

Author (s)	Article Title	Journal Name	Chemistry Topic	Learning outcome (s)
(Silva & Vasconcelos, 2026)	Integrating interactive simulations in higher education: the 5E-FLEX model	Discover Education	Solution concentration	Conceptual understanding
(Pitaloka, Muntholi, & Dasianto, 2025)	Learning Cycle 5E through Interactive Simulator to Improve Understanding of Molecular shapes and Chemistry Identity	Hydrogen: Jurnal Pendidikan Kimia	Molecular shapes	Conceptual understanding and chemistry identity
(Ijirana et al., 2025)	Enhancing Argumentation Skills of Prospective Chemistry Teachers through the 5E Learning Cycle Model	Journal of Hunan University (Natural Sciences)	Chemical bonding, Chemical equilibrium, Acid–base, Organic chemistry	Construct scientific arguments, critical thinking and problem-solving skills
(Ronggopuro, Muntholib, Santoso, & Nenohai, 2025)	The Effect of the 5E Learning Cycle Model with Learning Journals on Students' Critical Thinking in Thermochemistry	J-PEK (Jurnal Pembelajaran Kimia)	Thermochemistry	Critical thinking skills; Conceptual understanding; Scientific reasoning
(Ali, Ullah, Ahmad, & Ahmed, 2025)	Effect of 5e Instructional Model On Students Learning Outcomes in The Subject of Chemistry	Social Science Review Archives	General Chemistry	Conceptual understanding; Academic achievement; Problem-solving skills
(Sibarani & Nurfajriani, 2025)	Implementation of the Learning Cycle 5E Learning Model Assisted by Scaffolding to Improve Students' Learning Outcomes and Science Process Skills on Buffer Solution Material	Jurnal Pendidikan dan Pembelajaran Kimia	Buffer solution	Conceptual understanding; Science process skills
(Sudchanham & Cojorn, 2025)	Enhancing Stoichiometry Problem-Solving Skills through 5E Inquiry-Based Learning Combined with the FOPS Strategy	Jurnal Ilmu Pendidikan (JIP)	Stoichiometry	Problem-solving skills; Analytical thinking
(Arbain & Arianingrum, 2025)	LKPD dengan *Learning Cycle 5E* berorientasi NGSS terhadap Keterampilan *Developing And Using Model* dan *Constructing Explanation*	Jurnal Pendidikan Matematika dan Sains	Chemical bonding	Modeling skills; Scientific explanation
(Srichaitung, Supasorn, & Wuttisela, 2025)	Enhancing Conceptual Understanding of Climate Change in Non-Science Preservice Teachers Using DIY Model Kits	International Journal of Science Education and Teaching	Climate change (greenhouse effect, global warming, urban heat island)	Conceptual understanding
(Ridani & Arianingrum, 2024)	Development of Student Worksheets with Learning Cycle 5E Models on Solubility Product Constant Materials and Their Influence on Student Chemistry Literacy	Jurnal Penelitian Pendidikan IPA (JPPIPA)	Solubility Product Constant / KSP	Chemical literacy
(Varoğlu, Yilmaz, & Şen, 2024)	The Impact of the 5E Learning Model Improved with Concept Maps on Motivation	Center for Educational Policy Studies Journal (CEPS Journal)	Periodic Table	Learning motivation
(Tahira, Azhar, & Bajwa, 2024)	Evaluating the Effects of Problem Solving Model,	Pakistan Social Sciences	General Science	Academic achievement

Author (s)	Article Title	Journal Name	Chemistry Topic	Learning outcome (s)
	Traditional Instructional Model and 5E Instructional Model on Students Academic Achievement	Review (PSSR)		
(Twizeyimana, Shyiramunda, Dufitumukiza, & Niyitegeka, 2024)	Teaching and learning science as inquiry: an outlook of teachers in science education	SN Social Sciences (SN Soc Sci)	Solutions and Titration (Volumetric Titration)	Conceptual understanding, scientific process skills, attitude
(Ningthias, Listantia, & Sakaroni, 2024)	Melatih Scientific Explanation Siswa melalui Learning Cycle 5E berkonteks Socio-Scientific Issues (SSI)	Indonesian Journal of Educational Science	Salt Hydrolysis and Buffer Solution	Scientific explanation, argumentation, critical thinking
(Nja, Meremikwu, Odey, Anari, & Idiege, 2023)	Impact of 5Es Teaching Strategy on Chemistry Students' Academic Achievement in Electrochemical Cell Reactions in Calabar, Nigeria	International Journal of Education and Practice	Electrochemical Cell Reactions	Conceptual understanding, academic achievement, critical thinking
(Sotáková & Ganajová, 2023)	The effect of the 5E instructional model on students' cognitive processes and their attitudes towards chemistry as a subject	EURASIA Journal of Mathematics, Science and Technology	Chemical reactions and equations	Cognitive processes, critical thinking, conceptual understanding, attitude toward chemistry
(Tegegne & Kelkay, 2023)	Comparative study of using 5E learning cycle and the traditional teaching method in chemistry to improve student understanding of water concept: The case of primary school	Cogent Education	Water concepts (water hardness, water softening, water purification, water pollution)	Conceptual understanding, engagement, motivation
(Ernawati, Sugiyarto, Wiyarsi, & Ikhsan, 2023)	Analysis of Students' Learning Interest in the Implementation of the 5E Cycle Model on Chemical Equilibrium Material	Jurnal Penelitian Pendidikan IPA (JPPIPA)	Chemical Equilibrium	Learning interest
(Varoglu, Yilmaz, & Sen, 2023)	Effect of 5E Learning Cycle Assisted with Concept Maps on Conceptual Understanding	Pedagogical Research	Periodic Table Concepts (anion–cation, acid–base, ionic–covalent, metal–nonmetal, proton–electron relationships)	Conceptual understanding, concept linking
(Kibor, Ndeke, & Wambugu, 2023)	Effects of Mastery 5Es Constructivist Teaching Approach on Secondary School Students' Achievement in Chemistry	Education Quarterly Reviews	Effect of Electric Current on Substances (Electrochemistry: conductors, electrolytes, electrolysis)	Academic achievement, conceptual mastery
(Elfrida & Selly, 2023)	Differences of Students' Chemistry Learning Outcomes Based on the 5E Learning Cycle Model	Jurnal Pena Sains	Acid–Base (Acid–Base Theory, pH, Indicators)	Learning achievement, conceptual understanding
(Abukari, Najah, Samari, Gonyalug, & Agyei, 2023)	Improving Teaching and Learning of Organic Chemistry in Senior High Schools Using Collaborative Approaches	Universal Journal of Educational Research	Organic Chemistry	Conceptual understanding, application skills, scientific attitude, collaborative reasoning
(Dulmen, Visser, Pepin, & McKenney, 2023)	Teacher and student engagement when using learning materials based on the context of cutting-edge	Research in Science & Technological Education	Chemical Bonding, Hydrogen Bonding, Biochemistry context	Conceptual understanding, scientific inquiry skills, micro-macro reasoning, student

Author (s)	Article Title	Journal Name	Chemistry Topic	Learning outcome (s)
	chemistry research			engagement, motivation
(Ramdhani & Habiddin, 2023)	Reduksi Miskonsepsi Siswa Pada Materi Sifat Asam Basa Larutan Garam dengan Pembelajaran Learning Cycle-5E dan Mind-Mapping	Indonesian Journal of Educational Science (IJES)	Acid–Base, Salt Hydrolysis	Conceptual understanding, misconception reduction, scientific reasoning, active learning engagement
(Nzomo, Rugano, Njoroge, & Gitonga, 2023)	Inquiry-based learning and students' self-efficacy in Chemistry among secondary schools in Kenya	Heliyon	Chemistry Practical Learning, General Chemistry Concepts	self-efficacy, conceptual confidence, scientific inquiry skills, problem-solving ability
(Ha et al., 2023)	Teaching Science Using Argumentation-Supported 5E-STEM, 5E-STEM, and Conventional Didactic Methods: Differences in the Learning Outcomes of Middle School Students	Education Sciences	Separating Mixtures	Learning achievement, motivation, learning interest, higher-order thinking skills, critical thinking, problem-solving
(Savarimuthu & Susairaj, 2022)	Incorporating research literature and chemistry textbooks in 5E instructional model to reveal ambiguous oxidation state formalism of CuS for pre-service science teachers	Chemistry Teacher International	Oxidation State Formalism of Copper Sulfide (CuS)	Conceptual understanding, misconception correction, scientific reasoning, analytical thinking, evidence-based learning
(Eroğlu & Bektaş, 2022)	The effect of 5E-based STEM education on academic achievement, scientific creativity, and views on the nature of science	Learning and Individual Differences	Atomic System and Periodic Table	Academic achievement, scientific creativity, Conceptual understanding, problem solving, higher-order thinking
(Azizoğlu, Pekdağ, Sarıoğlan, & Kuzucu, 2022)	An Inquiry-Based Instruction on the Main Subatomic Particles: Enhancing High-School Students' Achievement and Motivation	Science Education International	Main Subatomic Particles	Academic achievement, conceptual understanding, inquiry skills, scientific reasoning, motivation
(Supasorn et al., 2022)	Grade-11 Students' Conceptual Understanding of Chemical Reaction Rate from Learning by Using the Small-Scale Experiments	Jurnal Pendidikan IPA Indonesia	Chemical Reaction Rate	Conceptual understanding
(Eroglu & Bektas, 2022)	The Effect of STEM Applications on the Scientific Creativity of 9th-Grade Students	Journal of Education in Science, Environment and Health (JESEH)	Atomic System and Periodic System	Scientific creativity
(Nurdini, Sutoyo, & Setiarso, 2021)	The Effectiveness of Learning Tools Using the 5E Learning Cycle Model to Improve Mastery of Concepts and Generic Science Skills	Jurnal Penelitian Pendidikan IPA (JPPIPA)	Electrolyte and Non-Electrolyte Solutions	concept mastery, generic science skills, observation skills
(Grau, Valls, Piqué, & Ruiz-Martín, 2021)	The long-term effects of introducing the 5E model of instruction on students' conceptual learning	International Journal of Science Education	Kinetic-molecular theory	conceptual understanding

Author (s)	Article Title	Journal Name	Chemistry Topic	Learning outcome (s)
(Fitriyana, Wiyarsi, Sugiyarto, & Ikhsan, 2021)	The Influences of Hybrid Learning with Video Conference and "Chemondro-Game" on Students' Self-Efficacy, Self-Regulated Learning, and Achievement toward Chemistry	Journal of Turkish Science Education	Hydrocarbon (alkane, alkene, alkyne, isomerism, physical properties)	self-efficacy, self-regulated learning
(Nursafitri, Santoso, & Sumari, 2021)	Pengaruh Model Pembelajaran Learning Cycle 5E dengan Analogi terhadap Pemahaman Konsep Siswa pada Materi Laju Reaksi	Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan	Chemical Reaction Rate	Conceptual understanding
(Ojeda, Dios, Pérez, Iñesta, & Dorrío, 2021)	Inquiry through Industrial Chemistry in Compulsory Secondary Education for the Achievement of the Development of the 21st Century Skills	Education Sciences	Industrial Chemistry (polymer, rubber, graphene, gelatin, plastic)	Critical thinking
(Sotáková, Ganajová, & Babinčáková, 2020)	Inquiry-Based Science Education as a Revision Strategy	Journal of Baltic Science Education	Changes in Chemical Reactions (reaction rate, exothermic–endothermic reactions, factors affecting reaction rate)	Conceptual understanding
(Gökalp & Adem, 2020)	The Effect of REACT and Computer-Assisted Instruction Model in 5E on Student Achievement of the Subject of Acids, Bases and Salts	Journal of Science Education and Technology	Acids, Bases and Salts	Student achievement

The 5E cycle proves its effectiveness as a learning strategy when each phase is implemented with a clear conceptual purpose and consistency (Elfrida & Selly, 2023; Fitriyana et al., 2021; Kibor et al., 2023). The engage phase determines the quality of the next phase because it is not only a phase for initial learning stimulation but also serves to diagnose students' prior knowledge and misconceptions so that the exploration conducted truly stems from conceptual needs, not merely aimless activities (Savarimuthu & Susairaj, 2022). In the exploration phase, students gain real learning experiences through laboratory practice or conducting preliminary investigations (Nja et al., 2023). The phase shows that the implementation of the 5E in chemistry is directed toward exploratory and hands-on activities. Then, in the explain phase, the results of students' exploration begin to be directed toward more coherent chemical explanations, so that previous activities do not stop at observation or discussion but transform into conceptual understanding(Abukari et al., 2023; Nurdini et al., 2021). In the Elaborate phase, chemical concepts are not merely understood but are reapplied in exercises, investigations, or different contexts so that new knowledge becomes integrated into students' understanding(Elfrida & Selly, 2023; Sotáková et al., 2020). In Evaluation phase, the quality of students' understanding of chemistry is assessed through their ability to apply concepts, evaluate the learning process, and determine whether learning objectives have been achieved (Dulmen et al., 2023; Grau et al., 2021).

A general pattern that the 5E model is implemented through various learning components, such as media, other strategies, and approaches in the context of chemistry education. Several articles analyzed found that the 5E model enriched with interactive simulations helped students understand the shapes of chemical molecules (Pitaloka et al., 2025). The NGSS-oriented 5E worksheets facilitated the modeling of chemical bonds (Arbain & Arianingrum, 2025) and the 5E model supported by concept maps helped students organize relationships between concepts in the periodic table(Varoglu et al., 2023). AR Interactive Particulate-Level Visualization (AriPV), Small-Scale Syringe-Vial Experiment (SSVE), and analogies used in reaction rates as a means to bridge concepts that are difficult to observe directly (Nursafitri et al., 2021; Supasorn et al., 2022). The integration of scaffolding in buffer solutions(Sibarani & Nurfajriani, 2025), learning journals in thermochemistry(Ronggopuro et al., 2025), FOPS in stoichiometry(Sudchanham & Cojorn, 2025), and the REACT strategy in acid, base, and salt topics

(Gökalp & Adem, 2020) have shown that 5E can also be directed to guide students' thinking processes, reflection, and problem-solving in chemistry learning to strengthen the processes of representation and construction of chemical concepts within the 5E phase.

The 5E learning cycle using approaches such as a Science, Technology, Engineering, and Mathematics (STEM) to the separation of mixtures (Ha et al., 2023), the Socio-Scientific Issues (SSI) context, which introduced issues such as acid rain, ZA fertilizer, swimming pool chlorine, ocean acidification, and drinking water quality as a context for elaborating on chemical concepts (Ningthias et al., 2024), and the context of cutting-edge chemical research (Dulmen et al., 2023) and industrial chemistry (Ojeda et al., 2021) showed that 5E can be used to connect chemical concepts with real-world problems, scientific practices, and students' social lives**.** Thus, the importance of the 5E in chemistry learning lies not merely in its sequence of phases but as a pedagogical framework that can be integrated with various learning components including media, strategies, and approaches so that each phase of the 5E model truly serves as a transitional space from phenomena to systematic, meaningful, and contextual chemical explanations.

Multiple representation in the implementation of the 5E learning cycle in chemistry education

Chemistry concepts require students to be able to connect various chemical representations so that the concepts can be comprehensively understood. In chemistry learning, concepts are not only presented through direct observation of phenomena but also through particle representations and abstract chemical symbols (Gkitzia, Salta, & Tzougraki, 2020). The implementation of the 5E learning cycle also utilizes multiple representations (macroscopic, submicroscopi and symbolic) (Gilbert & Treagust, 2009; Moju, Taylor, & Iweuno, 2025), although the depth of discussion is not always balanced and most of the analyzed articles do not explicitly mention multiple representation; however, these elements are still evident in the learning process conducted.

Macroscopic representation in the 5E learning cycle is presented to students by relating chemical concepts to their real lives, thereby bringing learning closer to their daily experiences and helping students understand concepts more concretely (Dulmen et al., 2023; Ha et al., 2023; Ijirana et al., 2025; Ningthias et al., 2024; Ramdhani & Habiddin, 2023; Ronggopuro et al., 2025; Silva & Vasconcelos, 2026; Srichaitung et al., 2025). Ojeda et al (2021) discussed this approach in the context of industrial chemicals such as rubber, graphene, gelatin, and plastic containers by utilizing local industries in students' environments to connect their real-world experiences with the production processes taking place in those industries. Macroscopic representation also helped students understand abstract concepts through laboratory activities, experiments and simulations (Ernawati et al., 2023; Eroglu & Bektas, 2022; Nzomo et al., 2023; Pitaloka et al., 2025; Ridani & Arianingrum, 2024; Sibarani & Nurfajriani, 2025; Twizeyimana et al., 2024). The same finding was reported in Tegegne & Kelkay (2023), which demonstrated that water-related concepts such as water hardness, water purification, water softening, and water pollution were explained at the macroscopic level by connecting students' prior experiences with in-class experimental activities.

Macroscopic representation in the implementation of the 5E tend to be positioned as a starting point in the engage and explore phases, as phenomena, everyday contexts, trigger questions, practical work, experiments, and simulations provide students with an empirical foundation before they are guided toward more abstract chemical explanations (Ali et al., 2025; Sotáková et al., 2020). Through the macroscopic representation, concepts are not immediately accepted as theory but become more closely connected to students' experiences during the learning process.

The submicroscopic representation is a crucial aspect in implementing the 5E in learning chemistry. This level serves as a bridge between the macroscopic and the symbolic level. Without submicroscopic reinforcement, 5E learning risks producing only engaging experimental activities or procedural symbolic solutions, without building a complete conceptual understanding (Supasorn et al., 2022). Discussions related to the submicroscopic level in the 5E cycle of chemistry learning typically occur during the explore, explain, elaborate, and evaluate phases. This is evident in Savarimuthu & Susairaj (2022) in which the concept of the oxidation number of CuS did not stop at symbolic rules but was brought into the explain phase through an explanation of the electronic structure of CuS and expanded upon in the elaborate phase through a review of the textbook. This pattern indicates that the submicroscopic level serves as a space for understanding ambiguous concepts that cannot be sufficiently explained by calculation procedures alone. In Sotáková et al. (2020) macroscopic experiences such as changes in heat and reaction rates through experiments were not left as observations but were directed toward explanations of chemical reactions and their application to other situations. Here, the submicroscopic is more implicit as an explanation linking experimental data to reaction concepts. It is evident that the submicroscopic representation in the 5E serves to add depth to chemistry learning. Observations and real-world contexts are not immediately considered understanding but must be translated into explanations regarding the underlying structures, particles, reactions, or mechanisms of the phenomena (Eroglu & Bektas, 2022; Eroğlu & Bektaş, 2022; Grau et al., 2021).

Symbolic representation appears when the results of observations or explorations begin to be interpreted into formulas, chemical equations, ionic notation, and mathematical calculations. This is evident in the research by Nurdini et al. (2021) which observed the light emission and bubble formation in electrolyte and non-electrolyte solutions phenomena not merely understood as macroscopic events but transformed into ionization equations and the symbolic language of chemistry. Furthermore, Based on Supasorn et al. (2022) discussed that reaction rate data is not merely interpreted as experimental results but is connected to reaction equations and chemical symbols before being reinforced through particle visualization. Symbolic representation in the 5E learning cycle tends to be more prominent in the explain, elaborate, and evaluate phases (Arbain & Arianingrum, 2025; Elfrida & Selly, 2023; Ha et al., 2023; Ijirana et al., 2025; Nja et al., 2023; Pitaloka et al., 2025; Ramdhani & Habiddin, 2023; Ridani & Arianingrum, 2024; Ronggopuro et al., 2025; Savarimuthu & Susairaj, 2022; Sibarani & Nurfajriani, 2025; Sotáková & Ganajová, 2023; Sudchanham & Cojorn, 2025; Varoğlu et al., 2024). This symbolic representation within the 5E serves as the formal language of chemistry that interprets observational findings and reasoning. However, this symbolic representation must remain linked to macroscopic and submicroscopic representations to prevent chemistry education from being confined solely to the process of manipulating chemical formulas or equations.

Analysis of learning outcomes in the 5E cycle in chemistry learning

The learning outcomes of implementing the 5E in chemistry learning are still dominated by the cognitive domain. Some studies use academic achievement and conceptual understanding as the primary indicators to measure the effectiveness of the 5E model (Table 1). It is consistent with the characteristics of each phase in the 5E learning cycle, which provides students with opportunities to explore phenomena, construct explanations, and re-evaluate the concepts they have learned. Through this process, improvements in students' understanding can be reflected in their learning scores. While many studies have focused on basic cognitive outcomes, others have explored more complex cognitive skills such as critical thinking (Ronggopuro et al., 2025), problem-solving (Sudchanham & Cojorn, 2025), scientific argumentation (Ijirana et al., 2025) and scientific explanation skills (Arbain & Arianingrum, 2025; Ningthias et al., 2024)

Several studies have also highlighted the importance of the affective domain, although research in this area remains less extensive than that in the cognitive domain. Several studies indicate that the 5E and related approaches are associated with motivation, interest, attitudes, perceptions, identity, self-efficacy, and self-regulated learning (Table 1). The affective domain is important because chemistry learning not only requires students to understand concepts but also demands interest, motivation, self-confidence, and engagement so that students are willing to persevere in facing concepts that are abstract, representational, and often considered difficult. Within the context of the 5E learning cycle that lacks affective support, students may participate in 5E activities but may not be deeply engaged in constructing understanding (Azizoğlu et al., 2022; Fitriyana et al., 2021). These findings indicate that the development of 5E research in chemistry is currently in a period of transition. On one hand, cognitive outcomes still dominate chemistry learning research because they are relatively easier to measure and compare. On the other hand, the growing attention to non-cognitive outcomes such as scientific argumentation, scientific explanation, creativity, chemistry identity, science process skills, 21st-century competencies, and affective aspects indicates a shift in perspective regarding the interpretation of learning success. This underscores that the effectiveness of chemistry learning can no longer be reduced solely to final test scores but must be understood more holistically through various complementary dimensions of learning outcomes.

Conclusion

Based on the results of the analysis of the 38 articles, the various implementations of the 5E model and its integration with learning media, other learning strategies, and learning approaches indicate its role as a flexible and relevant learning framework for various learning tools and contexts in chemistry education. The effectiveness of implementing the 5E learning cycle in chemistry education can be enhanced through the use of multiple representations that are coherently connected. The interconnection between macroscopic, submicroscopic, and symbolic representations is a crucial aspect in helping students build a more comprehensive conceptual understanding of chemical concepts. The scope of the learning outcomes examined indicates that this learning cycle not only supports the development of conceptual understanding but also has the potential to facilitate more meaningful chemistry learning. The findings of this study provide insights into the direction of 5E research in chemistry education and can serve as a reference for the development of instructional designs and future research.

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Author Contributions
Conceptualization, resources, methodology, writing—review and editing, project administration, data curation, writing—original draft preparation, S.J.B.P.G; Conceptualization, resources, writing—review, validation; W.W and T. W. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest

References

Abukari, M. A., Najah, A. N., Samari, J. A., Gonyalug, I. A., & Agyei, P. (2023). Improving Teaching and Learning of Organic Chemistry in Senior High Schools Using Collaborative Approaches. *Universal Journal of Educational Research*, *4*(2), 334–350.

Ali, Z., Ullah, H., Ahmad, S., & Ahmed, S. (2025). Effect of 5E Instructional Model on Students Learning Outcomes in The Subject of Chemistry. *Social Science Review Archives*, *3*(1), 2503–2515. https://doi.org/10.70670/sra.v3i1.560

Ambarwati, P., Anisa, N. N., Setiawati, A., Ajizah, D. N., Izzati, Z. A. N., & Erika, F. (2021). The 21st Century Skills on Chemistry Learning Based on Virtual Lab in Senior High School. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 27–39. https://doi.org/10.26740/jpps.v11n1.p27-39

Arbain, C., & Arianingrum, R. (2025). LKPD dengan Learning Cycle 5E berorientasi NGSS terhadap Keterampilan Developing And Using Model dan Constructing Explanation. *Jurnal Pendidikan Matematika dan Sains*, *13*(Special_issue), 166–175. https://doi.org/10.21831/jpms.v13iSpecial_issue.89301

Azizoğlu, N., Pekdağ, B., Sarıoğlan, A. B., & Kuzucu, G. (2022). An Inquiry-Based Instruction on the Main Subatomic Particles: Enhancing High-School Students' Achievement and Motivation. *Science Education International*, *33*(1), 75–85. https://doi.org/10.33828/sei.v33.i1.8

Boakye, S., & Nabie, M. J. (2022). The Effect of Using the 5E Instructional Model on Students' Performance in and Motivation to Learn Sine Rule and its Applications. *International Journal of Current Educational Studies*, *1*(1), 14–35. https://doi.org/10.5281/ZENODO.6625280

Bybee, R. W., Taylor, J. A., Gardner, A., Scotter, P. V., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications*. Colorado Springs.

Chen, S., Chen, H., & Li, Y. (2022). Study on Mathematical Concept Teaching in High School Based on 5E Instructional Model. *Research and Advances in Education*, *1*(1). https://doi.org/10.56397/RAE.2022.07.01

Darwis, D., Fitriani, E., & Styariyani, D. (2020). Pengembangan Modul Elektronik Berbasis Model Learning Cycle 5E Pada Pembelajaran Kimia Materi Asam-Basa. *JRPK: Jurnal Riset Pendidikan Kimia*, *10*(1), 130–138. https://doi.org/10.21009/JRPK.101.02

Dulmen, T. H. H. van, Visser, T. C., Pepin, B., & McKenney, S. (2023). Teacher and student engagement when using learning materials based on the context of cutting-edge chemistry research. *Research in Science & Technological Education*, *41*(4), 1617–1638. https://doi.org/10.1080/02635143.2022.2070147

Elfrida, D., & Selly, R. (2023). Differences of Students' Chemistry Learning Outcomes Based on The 5E Learning Cycle Model. *Jurnal Pena Sains*, *10*(2), 48–56. https://doi.org/10.21107/jps.v10i2.19275

Ernawati, Y., Sugiyarto, K. H., Wiyarsi, A., & Ikhsan, J. (2023). Analysis of Students' Learning Interest in the Implementation of the 5E Cycle Model on Chemical Equilibrium Material. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6122–6127. https://doi.org/10.29303/jppipa.v9i8.3041

Eroğlu, S., & Bektaş, O. (2022). The effect of 5E-based STEM education on academic achievement, scientific creativity, and views on the nature of science. *Learning and Individual Differences*, *98*, 1–11. https://doi.org/10.1016/j.lindif.2022.102181

Eroglu, S., & Bektas, O. (2022). The Effect of STEM Applications on the Scientific Creativity of 9th-Grade Students. *Journal of Education in Science, Environment and Health*, *8*(1), 17–36. https://doi.org/10.21891/jeseh.1059124

Fitriyana, N., Wiyarsi, A., Sugiyarto, K. H., & Ikhsan, J. (2021). The Influences of Hybrid Learning with Video Conference and Chemondro-Game on Students Self-Efficacy, Self-Regulated Learning, and Achievement toward Chemistry. *Turkish Journal of Science Education*, *18*(2), 233–248. https://doi.org/10.36681/tused.2021.62

Gilbert, J. K., & Treagust, D. (Eds.). (2009). *Multiple Representations in Chemical Education*. Dordrecht:

Springer Netherlands. https://doi.org/10.1007/978-1-4020-8872-8

Gkitzia, V., Salta, K., & Tzougraki, C. (2020). Students' competence in translating between different types of chemical representations. *Chemistry Education Research and Practice*, *21*(1), 307–330. https://doi.org/10.1039/C8RP00301G

Gökalp, F., & Adem, S. (2020). The Effect of REACT and Computer-Assisted Instruction Model in 5E on Student Achievement of the Subject of Acids, Bases and Salts. *Journal of Science Education and Technology*, *29*(5), 658–665. https://doi.org/10.1007/s10956-020-09844-6

Grau, F. G. I., Valls, C., Piqué, N., & Ruiz-Martín, H. (2021). The long-term effects of introducing the 5E model of instruction on students' conceptual learning. *International Journal of Science Education*, *43*(9), 1441–1458. https://doi.org/10.1080/09500693.2021.1918354

Ha, V. T., Chung, L. H., Hanh, N. V., & Hai, B. M. (2023). Teaching Science Using Argumentation-Supported 5E-STEM, 5E-STEM, and Conventional Didactic Methods: Differences in the Learning Outcomes of Middle School Students. *Education Sciences*, *13*(3), 1–20. https://doi.org/10.3390/educsci13030247

Ijirana, Santoso, T., Magfirah, Rahmawati, S., Nurmayanti, Y., & Irwan. (2025). Enhancing Argumentation Skills of Prospective Chemistry Teachers through the 5E Learning Cycle Model. *Journal of Hunan University Natural Sciences*, *52*(10), 90–99. https://doi.org/10.55463/issn.1674-2974.52.10.7

Jegstad, K. M. (2024). Inquiry-based chemistry education: A systematic review. *Studies in Science Education*, *60*(2), 251–313. https://doi.org/10.1080/03057267.2023.2248436

Joswick, C., & Hulings, M. (2024). A Systematic Review of BSCS 5E Instructional Model Evidence. *International Journal of Science and Mathematics Education*, *22*(1), 167–188. https://doi.org/10.1007/s10763-023-10357-y

Kibor, E. C., Ndeke, G. C. W., & Wambugu, P. W. (2023). Effects of Mastery 5Es Constructivist Teaching Approach on Secondary School Students' Achievement in Chemistry in Rongai Sub-County, Nakuru County, Kenya. *Education Quarterly Reviews*, *6*(2), 138–149. https://doi.org/10.31014/aior.1993.06.02.745

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). *Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement*. *6*(7), 1–6. https://doi.org/e1000097

Moju, M., Taylor, L., & Iweuno, B. (2025). Tackling the challenge of chemical representations through sensemaking practices in chemistry education. *Discover Education*, *4*(1), 352. https://doi.org/10.1007/s44217-025-00703-3

Ningthias, D. P., Listantia, N., & Sakaroni, R. (2024). *Melatih Scientific Explanation Siswa melalui Learning Cycle 5E berkonteks Socio-Scientific Issues (SSI)*. *7*(1), 70–80.

Nja, C. O., Meremikwu, A. N., Odey, E. O., Anari, M. I., & Idiege, K. J. (2023). Impact of 5Es teaching strategy on chemistry students' academic achievement in electrochemical cell reactions in Calabar, Nigeria. *International Journal of Education and Practice*, *12*(1), 13–25. https://doi.org/10.18488/61.v12i1.3553

Nurdini, I. S., Sutoyo, S., & Setiarso, P. (2021). The Effectiveness of Learning Tools Using the 5E Learning Cycle Model to Improve Mastery of Concepts and Generic Science Skills. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 184–190. https://doi.org/10.29303/jppipa.v7i2.672

Nursafitri, M., Santoso, A., & Sumari, S. (2021). Pengaruh Model Pembelajaran Learning Cycle 5E dengan Analogi terhadap Pemahaman Konsep Siswa pada Materi Laju Reaksi. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *6*(7), 1076–1081. https://doi.org/10.17977/jptpp.v6i7.14928

Nzomo, C. M., Rugano, P., Njoroge, J. M., & Gitonga, C. M. (2023). Inquiry-based learning and students' self-efficacy in Chemistry among secondary schools in Kenya. *Heliyon*, *9*(1), 1–10. https://doi.org/10.1016/j.heliyon.2022.e12672

Ojeda, M. D., Dios, M. Á. Q., Pérez, N. V., Iñesta, E. L., & Dorrío, J. B. V. (2021). Inquiry through Industrial Chemistry in Compulsory Secondary Education for the Achievement of the Development of the 21st Century Skills. *Education Sciences*, *11*(475), 1–17. https://doi.org/10.3390/educsci11090475

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., … Moher, D. (2021). *The PRISMA 2020 statement: An updated guideline for reporting systematic reviews*. https://doi.org/10.1136/bmj.n71

Petillion, R. J., & McNeil, W. S. (2020). Johnstone's Triangle as a Pedagogical Framework for Flipped-Class Instructional Videos in Introductory Chemistry. *Journal of Chemical Education*, *97*(6), 1536–1542. https://doi.org/10.1021/acs.jchemed.9b01105

Pitaloka, D. A., Muntholi, M., & Dasianto, D. (2025). Learning Cycle 5E through Interactive Simulator to Improve Understanding of Molecular shapes and Chemistry Identity. *Hydrogen: Jurnal Kependidikan Kimia*, *13*(3), 568–584. https://doi.org/https://doi.org/10.33394/hjkk.v

13i3.15842

Polanin, J. R., Austin, M., Taylor, J. A., Steingut, R. R., Rodgers, M. A., & Williams, R. (2024). Effects of the 5E Instructional Model: A Systematic Review and Meta-Analysis. *AERA Open*, *10*(1), 1–16. https://doi.org/10.1177/23328584241269866

Ramdhani, M. A., & Habiddin, H. (2023). *Reduksi Miskonsepsi Siswa Pada Materi Sifat Asam Basa Larutan Garam dengan Pembelajaran Learning Cycle-5E dan Mind-Mapping*. *6*(1), 1–14.

Ridani, M., & Arianingrum, R. (2024). Development of Student Worksheets with Learning Cycle 5E Models on Solubility Product Constant Materials and Their Influence on Student Chemistry Literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10215–10225. https://doi.org/10.29303/jppipa.v10i12.7522

Ronggopuro, B., Muntholib, M., Santoso, A., & Nenohai, J. A. (2025). The Effect of the 5E Learning Cycle Model with Learning Journals on Students' Critical Thinking in Thermochemistry. *J-PEK*, *10*(2), 90–104.

Savarimuthu, I., & Susairaj, M. J. A. M. (2022). Incorporating research literature and chemistry textbooks in 5E instructional model to reveal ambiguous oxidation state formalism of CuS for pre-service science teachers. *Chemistry Teacher International*, *4*(1), 103–115. https://doi.org/10.1515/cti-2022-0001

Sibarani, I. F., & Nurfajriani. (2025). Implementation of the Learning Cycle 5E Learning Model Assisted by Scaffolding to Improve Students' Learning Outcomes and Science Process Skills on Buffer Solution Material. *Jurnal Pendidikan Dan Pembelajaran Kimia*, *14*(2), 22–31. https://doi.org/10.23960/jpkv2.1423

Silva, R. A. D., & Vasconcelos, F. C. G. C. D. (2026). Integrating interactive simulations in higher education: The 5E-FLEX model. *Discover Education*, *5*(1), 1–19. https://doi.org/10.1007/s44217-026-01105-9

Sotáková, I., & Ganajová, M. (2023). The effect of the 5E instructional model on students' cognitive processes and their attitudes towards chemistry as a subject. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(9), 1–22. https://doi.org/10.29333/ejmste/13469

Sotáková, I., Ganajová, M., & Babinčáková, M. (2020). Inquiry-Based Science Education as A Revision Strategy. *Journal of Baltic Science Education*, *19*(3), 499–513. https://doi.org/10.33225/jbse/20.19.499

Srichaitung, P., Supasorn, S., & Wuttisela, K. (2025). Enhancing Conceptual Understanding of Climate Change in Non-Science Preservice Teachers Using DIY Model Kits. *International Journal of Science Education and Teaching (IJSET)*, *4*(3), 206–215. https://doi.org/10.14456/IJSET.2025.14

Sudchanham, K., & Cojorn, K. (2025). *Enhancing Stoichiometry Problem-Solving Skills through 5E Inquiry-Based Learning Combined with the FOPS Strategy*. *31*(1), 01–09. https://doi.org/http://dx.doi.org/10.17977/um048v31i1p01-09

Supasorn, S., Wuttisela, K., Moonsarn, A., Khajornklin, P., Jarujamrus, P., & Chairam, S. (2022). Grade-11 Students' Conceptual Understanding of Chemical Reaction Rate from Learning by Using the Small-Scale Experiments. *Jurnal Pendidikan IPA Indonesia*, *11*(3), 433–448. https://doi.org/10.15294/jpii.v11i3.36535

Tahira, R., Azhar, M., & Bajwa, M. J. (2024). *Evaluating the Effects of Problem Solving Model, Traditional Instructional Model and 5E Instructional Model on Students Academic Achievement*. *8*(3), 678–687. https://doi.org/https://doi.org/10.35484/pssr.2024(8-III)54

Tegegne, T. A., & Kelkay, A. D. (2023). Comparative study of using 5E learning cycle and the traditional teaching method in chemistry to improve student understanding of water concept: The case of primary school. *Cogent Education*, *10*(1), 1–17. https://doi.org/10.1080/2331186X.2023.2199634

Twizeyimana, E., Shyiramunda, T., Dufitumukiza, B., & Niyitegeka, G. (2024). Teaching and learning science as inquiry: An outlook of teachers in science education. *SN Social Sciences*, *4*(2), 1–25. https://doi.org/10.1007/s43545-024-00846-4

Ünlü, K. Z., & Dökme, İ. (2022). A systematic review of 5E model in science education: Proposing a skill-based STEM instructional model within the 21-st century skills. *International Journal of Science Education*, *44*(13), 2110–2130. https://doi.org/10.1080/09500693.2022.2114031

Varoglu, L., Yilmaz, A., & Sen, S. (2023). Effect of 5E learning cycle assisted with concept maps on conceptual understanding. *Pedagogical Research*, *8*(3), 1–12. https://doi.org/10.29333/pr/13167

Varoğlu, L., Yilmaz, A., & Şen, Ş. (2024). The Impact of the 5E Learning Model Improved with Concept Maps on Motivation. *Center for Educational Policy Studies Journal*, *14*(3), 189–211. https://doi.org/10.26529/cepsj.1504