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Overcoming The Challenges of Students' Self-Efficacy: A Review That Leads to Solutions in Chemistry Learning

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Abstract: Self-efficacy is essential in the process of achieving learning goals. Individuals with higher self-efficacy tend to choose to work on difficult and challenging tasks. This study aims to explore the solutions for students' self-efficacy challenges in chemistry learning. This study used a systematic literature review method. The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) approach was adopted for this review. The search was based on the keywords "self-efficacy", "students", "challenges", "solutions", and "chemistry learning" which resulted in articles using alternative terms to describe self-efficacy and specific interventions. A total of 13 research articles reviewed in this article were collected from databases such as SCOPUS, ERIC, and Google Scholar. The thematic analysis procedure was used to determine emerging themes. The six steps of thematic analysis are as follows: familiarization with the data, initial coding, search for topics, evaluation of themes, representation of themes and interpretation of results. The results of the review showed that there are several interventions that can improve students' self-efficacy in chemistry learning, including the use of game-based learning media, virtual learning media, and the application of certain models, strategies, and approaches such as problem-based learning (PBL), PBL-STEM, process oriented guided inquiry learning (POGIL), inquiry-based learning (IBL), SSI integration, metacognitive strategies, the implementation of efficacy-enhancing teaching, and also the use of core idea maps. Therefore, collaboration between educational institutions, schools and teachers is required in the implementation of this intervention. This collaboration will ensure a supportive environment, both inside and outside the classroom so that it has the potential to overcome students' self-efficacy challenges in chemistry learning.

Keywords: chemistry, learning, self-efficacy, solutions.

▪ INTRODUCTION

The primary aim of education is to empower students to proficiently grasp particular skills and subject matter. However, overlooking emotional aspects could significantly diminish the effectiveness of cognitive development and skill acquisition in the learning process (Griffith & Nguyen, 2006). Affective factors such as attitudes, self-efficacy beliefs, motivation, and anxiety play a role in shaping both the processes and results of student learning (Evans, 2007). Self-efficacy originates from a theoretical structure referred to as social cognitive theory. This theory elucidates that human accomplishments stem from the interplay between individual behavior and personal factors (e.g., thoughts, beliefs), and environmental conditions (Bandura, 1986, 1997). According to this perspective, self-efficacy shapes an individual's behavior and the interaction environment, being influenced by both their own actions and conditions (Schunk & Pajares, 2002). The concept of self-efficacy is understood as a multidimensional structure divided into different areas of competence, rather than just a general characteristic (Bandura, 2012).

Self-efficacy pertains to an individual's confidence in their capability to accomplish a specific task (Bandura, 1997). It is theorized that self-efficacy influences task selection,

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level of exertion, persistence, and eventual achievement (Bandura, 1986, 1997; Schunk, 1995). In choosing activities, students with higher self-efficacy usually choose challenging and demanding tasks, in contrast to students who have lower self-efficacy (Kurbanoglu & Akim, 2010). Perceived self-efficacy does not gauge an individual's actual skill level (Vishnumolakala et al., 2017). Self-efficacy refers to the perceived ability to learn or perform a behavior at a specified level. It is not the same as knowing what to do. Individuals assess their self-efficacy through their performance accomplishments, representative consequences of models, persuasion, and physiological cues (Schunk, 1991).

Bandura (1986) defined self-efficacy as an individual's confidence in their capacity to accomplish or successfully fulfill a given task (Bandura, 1986; Chen & Hsieh, 2023). They are more persistent in the face of difficulties they encounter. Despite failures, they tend to continue their efforts without feeling much of a shock in their feelings of self-efficacy (Baltaoğlu & Güven, 2019). According to Bandura, individuals construct their self-efficacy through the interpretation of four main influence messages, namely mastery experience, vicarious experience, social persuasion, and emotional and physiological states (Bandura, 1978, 1986). The fifth factor proposed by James Maddux as an influence factor of self-efficacy is the experience of imagination. Through the process of imagining and visualizing their success, individuals can also increasing confidence in their ability to achieve it (Maddux, 1995). The fact that behavioral choices are influenced by the level of self-efficacy leads to self-efficacy emerging as one of the dependable predictors of achievement and success when compared to other related factors (Ismail et al., 2023).

Self-efficacy influence the way a person makes choices, acts, and attempts when facing difficulties (Bandura, 1986; Rezai et al., 2022). It has an impact on learning achievement (Zusho et al., 2003). Self-efficacy differs across subjects, as students' confidence can vary significantly from one subject to another (Ferrell & Barbera, 2015). Those with high self-efficacy show a greater willingness to engage compared to their counterparts with lower self-efficacy, driven by their belief in the potential positive outcomes of their efforts. Exploring factors that enhance students’ self-efficacy is very important, considering its great influence on student achievement (Ferrell & Barbera, 2015). Self-efficacy within a subject can also enhance students' confidence in implementing their knowledge (Uitto, 2014). Furthermore, individuals with high self-efficacy may exhibit a heightened sense of competence, cognitive processes (Lin et al., 2020), academic performance (Wang et al., 2018), and achievement (Chang et al., 2018). Considering students' self-efficacy as an underlying trait, especially among those who face varying levels of cognitive load during science learning, is very important (Martin et al., 2021; Plass et al., 2009). Therefore, it can be concluded that self-efficacy is the level of confidence of students in their abilities when faced with a condition or problem. The level of individual’s self-efficacy varies depending on how the individual responds to each process they face. The higher the level of their confidence, the easier it will be for them to find solutions and the more positive thinking the individual will have. Individuals who have low self-efficacy will tend to have difficulty in completing every activity they face and tend to delay completing the activities they face. Self-efficacy is very important in the learning process to achieve learning goals.

As chemistry is a science based on experiments, conducting experiments in the laboratory is an essential part of learning chemistry. Therefore, affective dimensions of learning such as anxiety, attitude, and self-efficacy are considered as important things to consider from students in laboratory situations (Bowen, 1999). In the scope of experimental science, students in higher education often encounter anxiety for various reasons, such as the utilization of advanced equipment and complex procedures (Kamaruddin et al., 2015). One specific area where students commonly experience elevated levels of anxiety is in chemistry laboratory education. Five collective aspects of chemical anxiety have been identified, including working with hazardous chemicals, utilizing laboratory equipment, executing complex chemical procedures, facing time constraints, and working collaboratively to gather precise data (Kamaruddin et al., 2019). Additionally, the apprehension or fear associated with chemicals is termed “chemophobia” (Breslow, 1993). Students' perceptions of chemistry often diverge from its true essence (Huey, 2013). Chemistry is commonly perceived as a complex and highly theoretical science, leading to apprehension and eventually disappointment with the subject (Jegede, 2007).

In the past five years, literature reviews have only investigated self-efficacy in teachers (Gordon et al., 2023; Hutzler et al., 2019; Kwee, 2020; Matos et al., 2022; Menno et al., 2024). The literature review discussed the factors that influence teachers' self-efficacy and solutions to overcome teachers' low self-efficacy. Previous research showed that there are still many challenges in students’ self-efficacy. Meanwhile, students' self-efficacy, especially in chemistry learning which is often considered difficult, greatly affects their motivation, perseverance, and academic achievement. Without a deep understanding of effective intervention, students with low self-efficacy tend to face difficulties in understanding complex materials and give up more easily. Through this review, previous findings will be examined and analyzed to find potential interventions to improve students' self-efficacy.

Research Question

The study aims to explore solutions to students' self-efficacy challenges in learning chemistry. The research questions that guided the preparation of this article is:

1. How does the interventions overcome students' self-efficacy challenges in chemistry learning?

▪ METHOD

Research Design

This research is a systematic literature review, which is a methodological approach that aims to identify, evaluate and rigorously analyze relevant literature (Liberati et al., 2009). This review is conducted through a systematic procedure that produces valid findings that can be used as the basis for evaluation (Moher et al., 2009; Snyder, 2019). This study has employed the systematic literature review methods proposed by Liberati et al. (2009); Moher et al. (2009) based on the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) approach, which includes an identification process (keywords, search criteria, database, records extracted), screening (inclusion and exclusion criteria), eligibility (quality assessment) and includes records (Moher et al., 2010).

Search Strategy

Databases searched were electronic and concerned the areas of education and social science. The exact databases searched were Scopus, ERIC and Google Scholar databases. Published scientific research articles were searched and analyzed between February and July 2024. Publications published after this period were not included in this review. The keywords used for the selection of research articles were "*self-efficacy", "students", "challenges", "solutions", and "chemistry learning*".

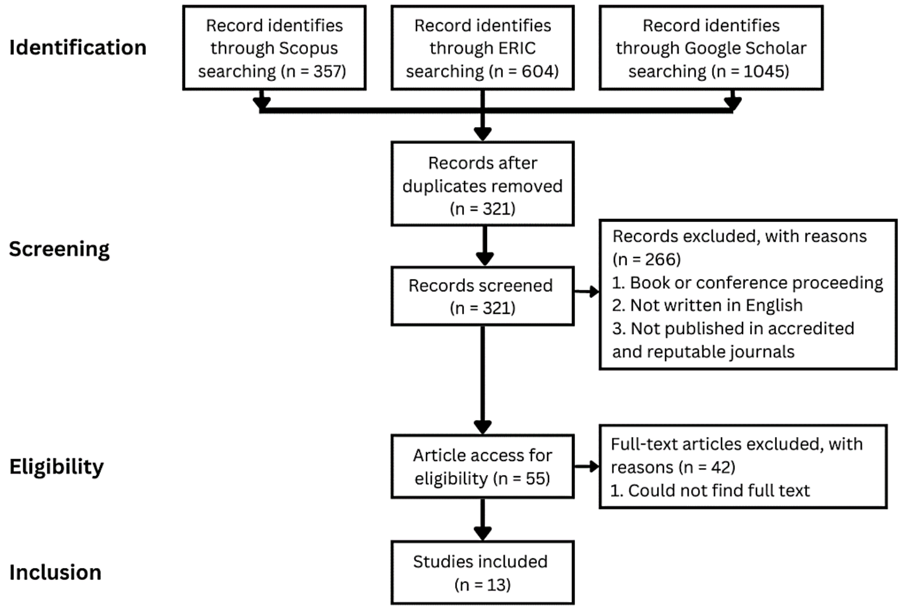

Figure 1. PRISMA flow diagram for searching and extracting data from the literature Adapted from Moher et al. (2009)

Inclusion and Exclusion Criteria

The articles were evaluated using several inclusion criteria. These criteria included: (1) research articles that focus on students' self-efficacy in chemistry learning, (2) discuss challenges or problems related to students' self-efficacy and their solutions in chemistry learning, (3) discuss potential solutions, include suggestions or interventions that already implemented to overcome the challenges or issues related to students' self-efficacy in chemistry learning, (4) studies involving participants from secondary to higher education, including university students, (5) research articles published between 2015 and 2024, (6) articles published in accredited and reputable journals, and (7) articles written in English. The selected research articles were not restricted to experimental studies but also encompassed mixed-methods or qualitative research. After reviewing the abstracts and full texts, 13 articles were reviewed in more depth.

The characteristics of the 13 selected articles based on research place, indexed journal, and research method in Table 1. Based on the continent, six studies were conducted in Asia, three in the America, two in Europe, and one each in Africa and Australia. All articles are from reputable journals. A total of 8 articles from Q1 indexed journals, 4 articles from Q2 indexed journals, and 1 article from Q3 indexed journal. The research methods used in the research article on the challenges and solutions to the problem of students' self-efficacy consist of quantitative approaches (9 studies) and mixed methods (4 studies). The most commonly utilized research method is the quantitative (quasi-experimental) approach (7 studies), which provides a detailed explanation of the interventions carried out. Figure 2 showed that a total of 8 articles reviewed discuss students' self-efficacy at the higher education level. Meanwhile, 5 articles reviewed focused on the self-efficacy of students in secondary school.

Table 1. Article characteristics

Author	Country	Indexed Journal	Research Method
(Hwang et al., 2024)	Taiwan	Q1	quasi-experimental
(Nzomo et al., 2023)	Kenya	Q1	mixed-methods
(Gungor et al., 2022)	Northern European	Q2	mixed-methods
(Semilarski et al., 2022)	Estonia	Q1	quasi-experimental
(Su, 2022)	Taiwan	Q2	mixed-methods
(Fitriyana et al., 2021)	Indonesia	Q2	quasi-experimental
(Fitriyana et al., 2020)	Indonesia	Q3	quasi-experimental
(Kolil et al., 2020)	India	Q1	quasi-experimental
(Gulacar et al., 2020)	United States	Q1	quasi-experimental
(Graham et al., 2019)	United States	Q2	survey
(Vishnumolakala et al., 2017)	Australia	Q1	quasi-experimental
(Mataka & Kowalske, 2015)	United States	Q1	mixed-methods
(Cheung, 2015)	Hong Kong	Q1	survey

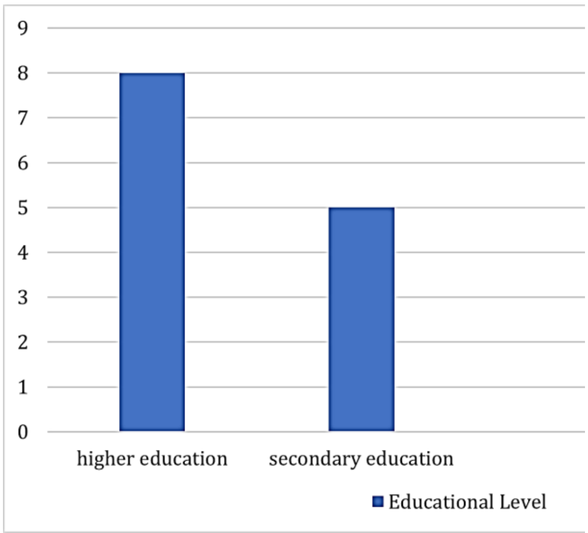

Figure 2. Number of articles based on education level

Data Analysis

The thematic analysis procedure described by Clarke and Braune (2013) was used to determine emerging themes. This is a qualitative data analysis technique that entails reviewing the data set and looking for emerging themes across the data. The six steps of thematic analysis are as follows: (1) familiarization with the data; (2) initial coding; (3) search for topics; (4) evaluation of themes; (5) representation of themes; and (6) interpretation of results (Clarke & Braun, 2013).

▪ RESULT AND DISSCUSSION

RQ. How does the interventions overcome students' self-efficacy challenges in chemistry learning?

The thematic analysis process resulted in three themes, (1) game-based learning media; (2) virtual learning media, and (3) models, strategies, and approaches. The themes are presented in Table 2. Despite limited literature on certain solutions, these findings underscore potential interventions that educators can adopt to enhance students' self-efficacy.

Table 2. Interventions used in the articles

Interventions	Articles	Percentage (%)
The use of game-based learning media	(Fitriyana et al., 2020, 2021; Hwang et al., 2024)	23.08
Virtual learning media	(Gungor et al., 2022; Kolil et al., 2020)	15.38
The use of models, strategies, and specific approaches	(Cheung, 2015; Graham et al., 2019; Gulacar et al., 2020; Mataka & Kowalske, 2015; Nzomo et al., 2023; Semilarski et al., 2022; Su, 2022; Vishnumolakala et al., 2017)	61.54
	Total	100

Theme 1. Game Based Learning Media

The results of the literature review indicated that game based learning (GBL) media overcome students' self-efficacy problems. Students' self-efficacy increased through their involvement in the game (Fitriyana et al., 2020). This was also explained by Fitriyana et al. (2021) that the utilization of chemondro-games combined with hybrid learning has a strong influence on student self-efficacy (Fitriyana et al., 2021). Game-based learning provides an opportunity to develop students' self-efficacy because it includes flexible learning materials (Hung et al., 2014). On the other hand, Hwang et al. (2024) found that students' self-efficacy can also be developed through a Concept Mapping-Based Digital Game-Based Learning system with a contextual learning approach. Students often struggle to understand concepts that are abstract and cannot be linked to daily life. Therefore, this can be overcome by implementing a contextual approach so that students are guided to apply scientific knowledge to real situations in daily life.

This review showed that overcoming students' elf-efficacy challenges in learning chemistry can also be done through the use of GBL media. First, flexibility with online technology. The use of GBL that can be accessed through mobile devices provides flexibility of time and place for students to learn. It is easier for students to learn independently, increasing their confidence in completing chemistry tasks. The combination of GBL and hybrid learning can also be more effective. The use of games outside the classroom and structured discussions in the classroom allowed students to more deeply master the material. Second, the development of games with an approach or model. GBL media needs to be implemented to increase students' self-efficacy while encouraging deep reflection. Otherwise, students may be more likely to focus on the game itself and ignore the importance of deeply understanding the material and reflecting on the significant connections between scientific concepts. The pressure on students to follow the rules of the game and strive to achieve challenging goals in the game will foster students' self-efficacy. Therefore, students' learning experience through GBL media can be developed by applying a learning model or approach to the game. Third, the integration of immediate feedback and game level customization. Game-based learning can be developed to provide immediate feedback based on students' performance in each stage of the game. In addition, the game has the ability to automatically adjust the level of difficulty according to the student's ability level allowing for more personalized learning. Students will feel challenged without feeling overburdened, which can increase their self-efficacy gradually. This creates a more enjoyable learning environment and supports students in facing complex chemistry challenges with greater confidence.

Theme 2. Virtual Learning Media

There are many negative assumptions about chemistry such as chemistry as a dangerous subject to learn, risky chemicals, chemistry is closely related to explosions, chemistry that requires numerical problem solving, understanding chemical principles, memorization of abstract facts and concepts (Kamaruddin et al., 2019). Meanwhile, the rapid advancement of technology in education has made it easier for educators to develop learning media (Aldresti et al., 2023; Simanjuntak et al., 2022). A virtual lab (VL) is a platform featuring remote laboratory simulations and experiments, enabling students to grasp scientific concepts governing experiments more effectively through visualization and hands-on practice (Jones, 2018). VL have been demonstrated to be more effective in enhancing understanding of challenging concepts and fostering self-efficacy in scientific inquiry (Husnaini & Chen, 2019). VL facilitate interactivity to enrich hands-on learning experiences, conducting some experiments beyond activities in physical laboratories, and conducting pre-laboratories (Kolil et al., 2020).

VL give students the opportunity to repeat difficult experiments over and over again until they succeed. In addition, VL also create a safe environment for students to conduct experiments without fear of physical risks and equipment damage. Students can improve their procedural and contextual understanding by varying the parameters on the VL. This assertion is corroborated by the research conducted by Gungor et al. (2022), who discovered that online pre-laboratory preparation involving diverse learning activities bolstered students' laboratory experience. This enhancement was evidenced by improvements in students' readiness, engagement, self-efficacy, efficiency, and performance (Gungor et al., 2022).

Online pre-lab preparation resulted in increased student independence and self-efficacy in operating laboratory equipment. With emerging self-efficacy, students needed less guidance with fewer errors during experiments. Virtual laboratories enable effective use of resources for distance learning (Gungor et al., 2022). Engaging in practical activities subsequent to VL pre-laboratory interventions holds promise for cultivating self-efficacy beliefs and alleviating laboratory anxiety. Eventually, the use of this VL supports the educational paradigm in Indonesia that emphasizes student-centered learning (Aldresti et al., 2023).

These findings suggest that VL has great potential to address students' self-efficacy challenges. First, the integration of VL in the educational curriculum should be considered so that it can help students understand concepts visually and interactively. Second, utilizing the online pre-laboratory. As preparation for physical laboratory activities, students should participate in Virtual Learning (VL) simulations before conducting physical laboratory activities. This can provide an opportunity to repeat difficult experiments in VL thus increasing their confidence and conceptual understanding without pressure or risk. By encouraging students to conduct experiments independently, VL can improve self-efficacy and independence in the use of laboratory equipment. Third, personalized learning with adaptive VL. VL technology can be developed to have adaptive learning features that can be tailored to the needs of each student. For example, the VL platform can measure students' level of understanding through quizzes or pre-tests, then provide experimental modules that match their abilities. This helps avoid the frustration of tasks that are too difficult or too easy, thus boosting student confidence.

Theme 3. Models, Strategies and Approaches

Based on a review of several international articles, there are certain models, strategies, and approaches such as PBL, PBL-STEM, SSI integration, metacognitive strategies, the use of efficacy-enhancing teaching, and also core idea maps. The selection of an inappropriate model/approach/method greatly affects students' enthusiasm for learning (Linda et al., 2024). Problem-based learning (PBL) is a learning approach in which students are assigned to solve real-world problems that do not have a clear structure. At the first stage of PBL, the teacher must be able to design or guide students to real-life problems (Simanjuntak & Purwaningsih, 2024). Typically, students collaborate in groups to tackle these unstructured problems. PBL enhances students' self-efficacy in chemistry due to the mastery experiences inherent in the PBL process. Students have to think about their own activities and apply chemical knowledge to learn. Providing students with real-life challenges and projects can enhance their self-efficacy in planning and conducting experiments, as they have full responsibility in the learning process (Mataka & Kowalske, 2015). In-depth and hands-on PBL-STEM teaching activities also augment students' enthusiasm for learning about careers and enhance their capacity for comprehension, problem-solving, self-efficacy, and cooperative group work (Su, 2022).

Chemistry learning with POGIL encourage students to understand chemistry content and apply it in their daily lives. The experience students acquire through POGIL classes can significantly influence their capacity to communicate with peers, apply theoretical principles, and engage in skillful scientific inquiry throughout their chemistry learning journey (Vishnumolakala et al., 2017). POGIL enhance students' self-efficacy by synchronizing the cognitive characteristics of structured learning materials and independent small group interactive learning (Vishnumolakala et al., 2017). In addition, incorporating inquiry-based learning (IBL) into chemistry practical lessons also fosters high levels of self-efficacy (Nzomo et al., 2023).

Gulacar et al. (2020) found that students' ability to search for relevance in SSI topics can increase their chemistry self-efficacy (Gulacar et al., 2020). SSI are current real-world problems that require a science background in order to form an informed opinion (Stolz et al., 2013). SSI should be authentic, relevant, open to judgment, debatable, and grounded in the subject at hand (Stolz et al., 2013). SSI challenge students to use their scientific background to engage in public policy debates, thus improving their chemistry and critical thinking skills (Feierabend & Eilks, 2011).

Direct teaching in metacognitive strategies combined with practice in chemistry learning can enhance students' self-efficacy. This includes six key strategies for effective learning, which are knowing effective learning strategies according to the situation and task at hand, being able to use the chosen strategy effectively, knowing when it is necessary to change the strategy used, increasing the accuracy of metacognitive assessment of one's ability to solve problems or tasks, practicing consciously with metacognitive strategies to achieve automation in the use of these strategies, as well as choosing strategies to approach new problems, monitoring the implementation of the approach, and assessing the success of the approach (Graham et al., 2019). A study conducted by Cheung (2015) also showed that efficacy-enhancing teaching can positively influence student self-efficacy in chemistry. The teaching includes instructional strategies such as providing tasks that match the level of difficulty so that students can complete it successfully, teaching students how to find the main idea to solve chemistry problems, providing positive feedback to students, and creating a supportive learning environment (Cheung, 2015).

The utilization of knowledge construction tasks, knowledge visualization, collaboration, and interdisciplinary connections aids students in linking prior knowledge with new information. Disciplinary core ideas (DCIs) and interdisciplinary core ideas (ICIs) serve as valuable tools for students to describe phenomena and address ill-structured problems (Semilarski et al., 2019). In science learning, DCI and ICI are essential for improving students' concept understanding and increasing their self-efficacy. Both help connect prior knowledge with new knowledge (Soobard et al., 2018). Combining DCI and ICI enables the development of broader conceptualization and incorporation of knowledge. As a result, the learning process becomes more meaningful and closer to society (Sukhov et al., 2018). A study showed that conceptualization of learning can help students make connections between significance and collective experience. This will boost students' confidence and encourage meaningful learning (Bandura, 1986; Semilarski et al., 2022; Weick et al., 2005).

The findings of this study provided several recommendations for further research. First, develop game-based chemistry learning with more extensive interactive and adaptive features. This research can also explore the effect of interactive features such as immediate feedback and automatic difficulty adjustment. Second, develop more personalized and adaptive virtual laboratory media. Research needs to investigate the effect of virtual laboratories with adaptive features designed according to students' abilities towards students' self-efficacy at different levels of education. Third, examine the integration of various learning models such as PBL, POGIL, and contextual approaches based on Socio-Scientific Issues (SSI) with technologies (VL and GBL) that can enhance students' self-efficacy in chemistry learning.

▪ CONCLUSION

The research findings showed that the use of game-based learning media, virtual learning media, the application of certain models, strategies, and approaches such as PBL, PBL-STEM, POGIL, inquiry-based learning (IBL), SSI integration, metacognitive strategies, implementation of efficacy-enhancing teaching, and also the use of core idea maps in the chemistry learning process can overcome students' self-efficacy challenges in learning chemistry. Better implementation of these interventions can be obtained through cooperation between the government, educational institutions, schools and teachers. The government can provide policies and resources that support students' skill development, while educational institutions and schools can design relevant curricula. Teachers as the main role can actualize the implementation of various interventions above so as to increase students' confidence in the chemistry learning process. This collaboration will ensure a supportive environment, both inside and outside the classroom, to overcome students' self-efficacy challenges in chemistry learning.

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