



Integration of STEAM Approach in Chemistry Learning to Develop Higher Order Thinking Skills (HOTS): Literature Review

Muhammad Rifqi Zidan*, Umi Nur Khamidah, Ifah Silfianah

Chemistry Education, Faculty of Education and Teacher Training, Islamic State University of Sayyid Ali Rahmatullah.

Jl. Mayor Sujadi Timur No. 46 Tulungagung, Indonesia.

*Corresponding-email: zidanmuhr2888@gmail.com

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Abstract: Integration of STEAM Approach in Chemistry Learning to Develop Higher Order Thinking Skills (HOTS): Literature Review. This study aims to conduct a literature review on the integration of STEAM in chemistry education with a particular focus on the development of higher-order thinking skills (HOTS). The review was carried out using a literature study method guided by the PRISMA protocol and involved the analysis of 34 published articles within the period of 2018–2025. The findings indicate that HOTS developed through the STEAM approach include creative thinking—as the most frequently developed and examined skill—followed by critical thinking and problem-solving. Other skills such as reflection, decision-making, logical reasoning, and metacognition remain less emphasized. STEAM has proven effective in fostering various HOTS when applied independently or integrated with innovative models such as Project-Based Learning (PjBL), Problem-Based Learning (PBL), Design Thinking, RADEC, Inquiry, Deep Learning, Gamification, and Blended Learning. Instructional media developed, including Worksheet (LKPD), E-Worksheet (E-LKPD), and E-Modules, have been proven effective in developing students' HOTS.

Keywords: HOTS, STEAM, Chemistry Learning, PRISMA, Creative Thinking

Abstrak: Integrasi Pendekatan STEAM dalam Pembelajaran Kimia untuk Mengembangkan Higher Order Thinking Skills (HOTS): Studi Literatur. Penelitian ini bertujuan untuk melakukan studi literatur mengenai integrasi STEAM dalam pembelajaran kimia yang berorientasi pada pengembangan keterampilan berpikir tingkat tinggi (HOTS). Penelitian ini dilakukan dengan menggunakan metode studi literatur mengikuti pedoman PRISMA dan menganalisis 34 artikel terpublikasi pada rentang tahun 2018–2025. Hasil menunjukkan bahwa HOTS yang dikembangkan melalui pendekatan STEAM meliputi berpikir kreatif, sebagai keterampilan yang paling banyak dikembangkan dan diteliti, diikuti oleh berpikir kritis dan pemecahan masalah. Keterampilan lainnya seperti refleksi, pengambilan keputusan, penalaran logis, dan metakognisi kurang mendapat perhatian. Pendekatan STEAM terbukti efektif dalam mengembangkan berbagai jenis HOTS, baik ketika diterapkan secara mandiri maupun ketika diintegrasikan dengan model inovatif seperti *Project-Based Learning (PjBL)*, *Problem-Based Learning (PBL)*, *Design Thinking*, *RADEC*, *Inquiry*, *Deep Learning*, *Gamification*, dan *Blended Learning*. Media pembelajaran yang dikembangkan berupa lembar kerja peserta didik (LKPD), E-LKPD, dan E-Modul terbukti efektif dalam mengembangkan HOTS peserta didik.

Kata kunci: HOTS, STEAM, Pembelajaran Kimia, PRISMA, Berpikir Kreatif

■ INTRODUCTION

The implementation of STEAM (Science, Technology, Engineering, Arts, Mathematics STEAM) approach is important because it equips students with comprehensive technological skills and knowledge, making it a crucial foundation for preparing generation that capable of navigating complexity and contributing positively in the 21st century (Firmansyah & Aslan, 2025). The STEAM approach is beneficial in developing 21st century skills through hands-on experiences that stimulate creative thinking across disciplines (Mu'minah, 2021). STEAM provides space for students to explore, evaluate, and solve projects innovatively (Junior & Sousa, 2023; Muntomimah & Wijayanti, 2021; Perignat & Katz-Buonincontro, 2019). STEAM project design in learning has a fairly good impact on HOTS, and a greater impact on their creative thinking, problem solving abilities and critical thinking (Xu, Ge, Gao, & Lu, 2025).

HOTS prepare students to develop in advanced reasoning and become a skill required in 21st-century learning (Hardiansyah, Pohan, & Hasanah, 2024; Jaenudin, Chotimah, Farida, & Syarifuddin, 2020). A study conducted by Kania and Kusumah shows that several experts define HOTS in terms of thinking skills, namely critical thinking, creative thinking, problem-solving, decision-making skills, logical reasoning, reflective, and metacognitive thinking (Kania & Kusumah, 2025). Brookhart's definition of HOTS is transfer, critical thinking, and problem solving, then categorizes higher-order thinking in categories illustrating how to assess various aspects of thinking in the form of analysis, evaluation, and creation (the "top end" of Bloom's taxonomy), logical reasoning, judgment, critical thinking, problem solving, creativity and creative thinking (Brookhart, 2010). Thus, HOTS encompass critical thinking, creative thinking, problem-solving, decision-making, logical reasoning, reflective, metacognitive, analysis, evaluation/judgement, and creation (the "top end" of Bloom's taxonomy). HOTS serve as a crucial asset for students in science education, as these skills enable them to critically analyze, evaluate, and solve complex problems or phenomena arising from various scientific issues (Fadila, Meriza, Yolida, & Marpaung, 2025). HOTS should be implemented and developed in learning activities (Liu, Ma, Sun, Zhu, & Xu, 2022).

HOTS are essential in the study of chemistry to achieve meaningful learning, and basic mastery is crucial as a fondation for developing more advanced cognitive abilities (Ghani, Ibrahim, Yahaya, & Surif, 2017). However, chemistry at the Senior High School level or equivalent is still being subject with little interest because students consider chemistry is a difficult subject to learn, even feared (Maksum, Latifah, Al-anshori, & Rachman, 2019). There are challenges in chemistry learning in the form of learning difficulties experienced by students, which are caused by a lack of interest and attention during the learning process, lack of student readiness to accept new concepts, lack of emphasis on essential prerequisite concepts, lack of conceptual understanding, and ineffective learning strategies (Hakim, Astafani, & Resmawati, 2024). Based on these issues, a new approach or method is required in order to eliminate the stigma that chemistry is difficult to understand. An alternative that can be apply to enhance chemistry understanding is the implementation of the STEAM learning approach (Pujiyati, 2020).

As an interdisciplinary field of science, chemistry is suitable to be integrated into the STEAM approach, because it supports students to grasp the relationship between different disciplines and its applications in real-world situation (Xoliyorova, Tilyabov, & Pardayev, 2024). Chemistry is the study about matter, changes, interactions, and the rules underlying these changes. Studying chemistry means combining the principles of education and chemistry, therefore contextualized chemistry learning such as the STEAM

approach is essential to help students solve real-life problems using their chemical knowledge (Indriyanti, Kartika, & Susanti, 2021). When real-world contexts are integrated in the learning process through technology-based STEAM education, students' interest in chemistry is fostered, students become aware of chemical phenomena, students' independent research is engaged, and students' can express their opinions about the processes involved, therefore learning effectiveness is enhanced (Ergashovich, 2023).

Results of field research have demonstrated that the STEAM approach exerts a positive influence on the domain of chemistry education, particularly with regard to enhancing students' learning outcomes (Sugiarti & Fatimah, 2023; Witriana, 2023), in comparison with conventional instructional methods, such as lectures, STEAM learning has been found to be more efficacious in promoting learning outcomes (Sheila Wann Lubis & Rahmania, 2022). Furthermore, the STEAM approach has been demonstrated to enhance students' science and chemistry literacy in various domains (Y. Rahmawati, Ridwan, Mardiah, & Afrizal, 2020; Rusmansyah, Anjaini, & Kusasi, 2021). STEAM is an effective way to help students understand chemistry concepts, therefore STEAM-based learning can be applied as a practical activity in chemistry classes for high school students (Ritmuan, Chonchaiya, & Duangpummet, 2021).

Literature study shows that the STEAM approach contributes significantly enhances the quality of chemistry learning particularly with regard to enhancing students' critical and creative thinking skills (Sugita, Sabela, Mayang Sari, Idayanti, & Erika, 2025). Embedding TPACK in STEAM-based chemistry learning tends to yield positive influences on the quality of learning processes and outcomes (Bahriah, Solihatin, & Hanafi, 2024). Furthermore, extant literature study on STEAM and the enhancement of HOTS predominantly discuss science learning in general (Xu *et al.*, 2025).

Only two studies have examined STEAM integration in chemistry education: one on STEAM in general and one on TPACK-based integration to enhance critical, creative thinking, and learning outcomes. However, the existing literature studies have yet to explore the integration of STEAM in chemistry learning with a specific focus on students' HOTS. Therefore, the study is design to perform a literature review on the integration of STEAM in chemistry learning, with a focus on students' HOTS, thereby the following research questions were established:

RQ1. How has the STEAM approach in chemistry learning trend to develop HOTS over the last ten year (2016-2025)?

RQ2. What types of HOTS can be developed through the STEAM approach in chemistry learning?

■ METHOD

The literature review method was used to answer the objectives of this study. The objective of this study is to furnish comprehensive insights into the integration of STEAM in chemistry learning, with a particular emphasis on HOTS enhancement. This research follows the updated 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) which emphasize several aspects to ensure a transparent, replicable, and scientifically adequate systematic review. (Page *et al.*, 2021; Sarkis-Onofre, Catalá-López, Aromataris, & Lockwood, 2021).

Search Strategy

The literature search was conducted using Publish or Perish software connected to the Google Scholar database, and manual searches of articles published between 2016 and 2025 was conducted. The initial search was executed by integrating keywords with Boolean operators: "STEAM" AND ("higher order thinking skills" OR "HOTS") AND ("chemistry learning" OR "chemistry education") (Zhou et al., 2006). The second search was done by combining the keywords: "STEAM" AND ("keterampilan berpikir tingkat tinggi" OR "kemampuan berpikir tingkat tinggi" OR "HOTS") AND ("pembelajaran kimia" OR "pendidikan kimia"). Subsequently, a manual search was conducted using Google Chrome.

Inclusion Criteria and Exclusion Criteria

The Inclusion Criteria applied in this literature review are as follows:

- IC1. The research is published in the form of a journal article.
- IC2. The research is written in English or Indonesian.
- IC3. The research is peer-reviewed.
- IC4. The research is not listed in another databases.
- IC5. The research is available in full text.
- IC6. The research is conducted in the educational environment (higher education or university).
- IC7. The research is included a research or description of the STEAM approach in chemistry learning to develop HOTS.
- IC8. The research is used other methods than literature review

The Exclusion Criteria applied in this literature review are as follows:

- EC1. Books, book chapters, theses, proceedings, magazine, and website.
- EC2. The research is not written in English or Indonesian.
- EC3. The research is not peer-reviewed.
- EC4. The research is listed in other databases.
- EC5. The research is not available in full text.
- EC6. The research is not conducted in the educational environment.
- EC7. The research is not included a review, research or description of the STEAM approach in chemistry learning to develop HOTS.
- EC8. The research is used a literature review method.

Data Collection and Analysis

The first stage carried out was identification, 1,238 publications from Google Scholar search and 401 publications from manual search were obtained, resulting in a total of 1,639 publications. After the duplicate removal stage, based on Inclusion Criteria 4 and Exclusion Criteria 4, 1282 eligible publications were obtained using Microsoft Excel software. Furthermore, screening stage is carried out based on Inclusion Criteria (IC1, IC3, IC5) and Exclusion Criteria (EC1, EC3, EC5) using Microsoft Excel software and checking the URL of the publications, 801 publications are obtained. The last stage, based on Inclusion Criteria (IC2, IC6, IC7, IC8) and Exclusion Criteria (EC2, EC6, EC7, EC8) by reading the full text of article, total of 34 publications that passed the selection process were obtained.

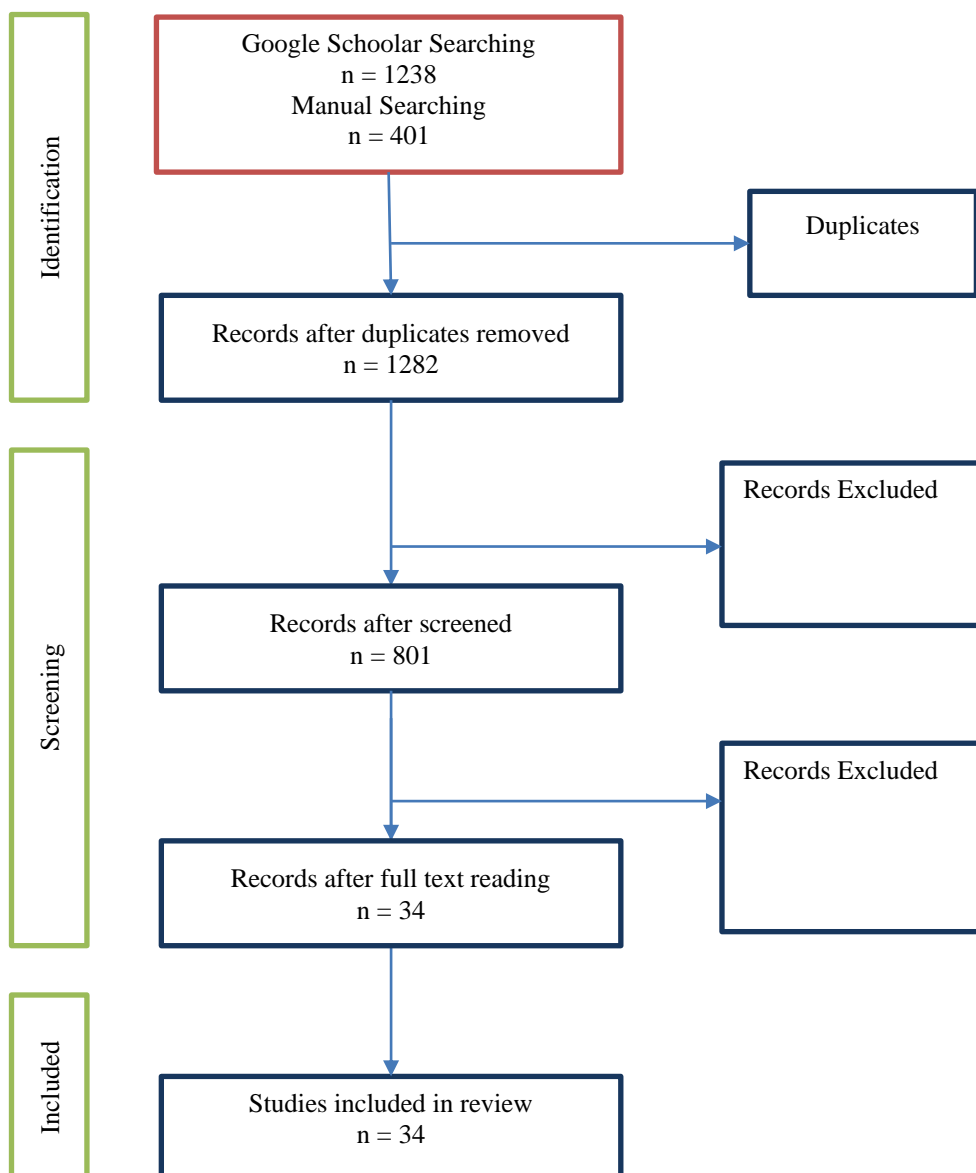


Figure 1. PRISMA Flow Chart

■ RESULT AND DISCUSSION

34 publications were identified, from a total of 1,282 publications, as eligible for review. The findings and discussion are organized according to the two research questions that guided this study.

RQ1. How has the STEAM approach in chemistry learning trend to develop HOTS over the last ten year (2016-2025)?

As illustrated in Figure 2, publications discussing the application of STEAM to develop HOTS in chemistry learning began to appear in 2018, experienced a significant increase in 2022, and reached the highest number of publications in 2024. The most frequently discussed skills were creative thinking (n=21), followed by critical thinking (n=17), problem solving (n=8), and other skills such as reflection, decision making, logical reasoning, metacognitive, analyze, and evaluation (each n=1), while creation skills

did not receive any attention (n=0). Some articles discuss more than one HOTS concurrently. Creative thinking has been most widely investigated because inclusion of the arts in STEAM learning encourages students to develop unique and original ideas, thereby fostering divergent thinking, which constitutes creative thinking. This fact indicates a research bias toward creation skills, representing the highest level in Bloom's taxonomy, remains neglected. Therefore, future research should focus on exploring these underrepresented skills to ensure a more comprehensive implementation of STEAM in developing the full type of HOTS.

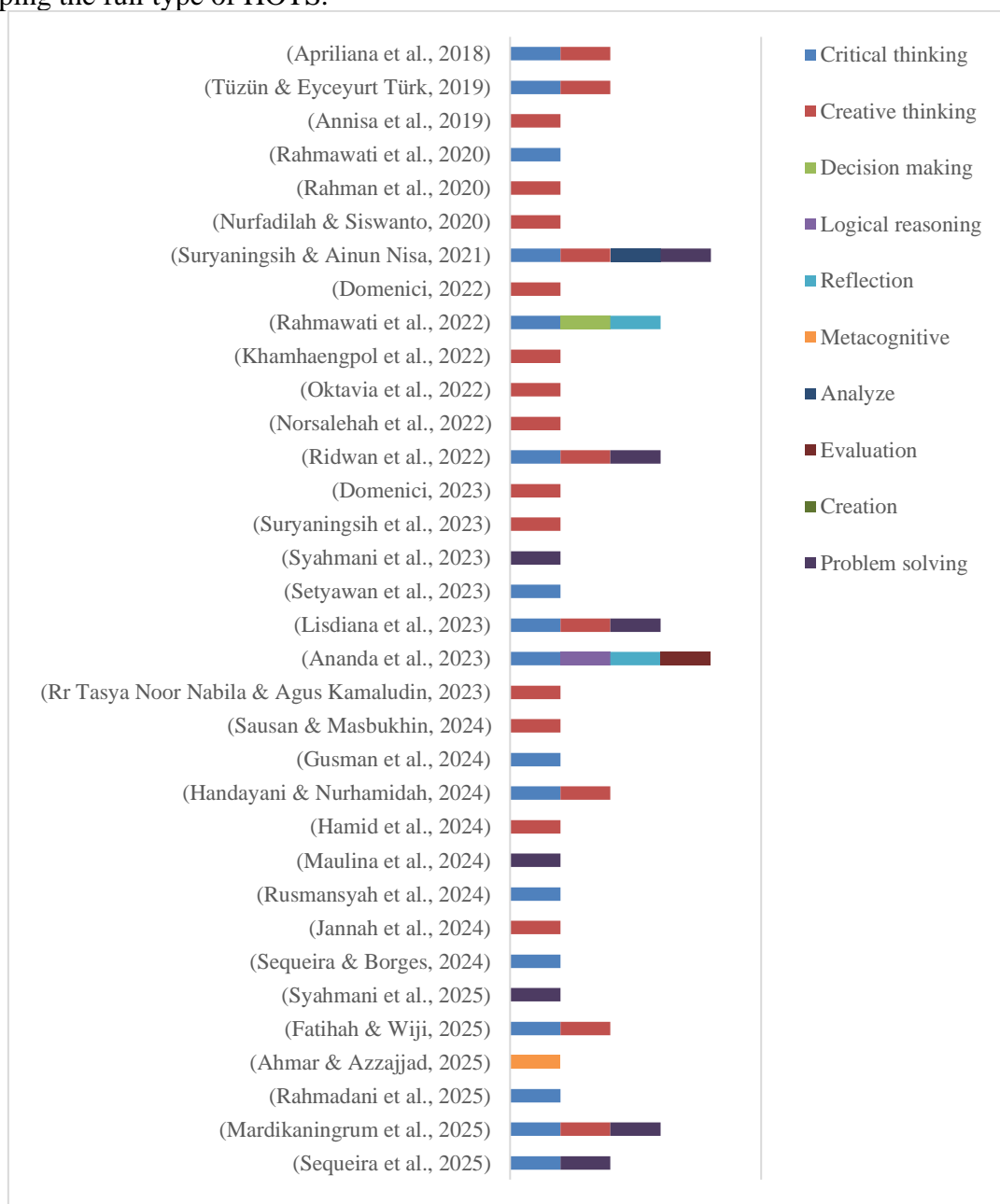


Figure 2. List of Articles and types of HOTS

As illustrated in Figure 3, the PjBL learning model is the most widely implemented model to develop students' HOTS. The dominance of the PjBL model is related to its

suitability for STEAM implementation, which emphasizes project-based, collaborative, and contextual learning while integrating the dimension of art. Furthermore, several publications do not integrate STEAM with the other learning model or learning approach.

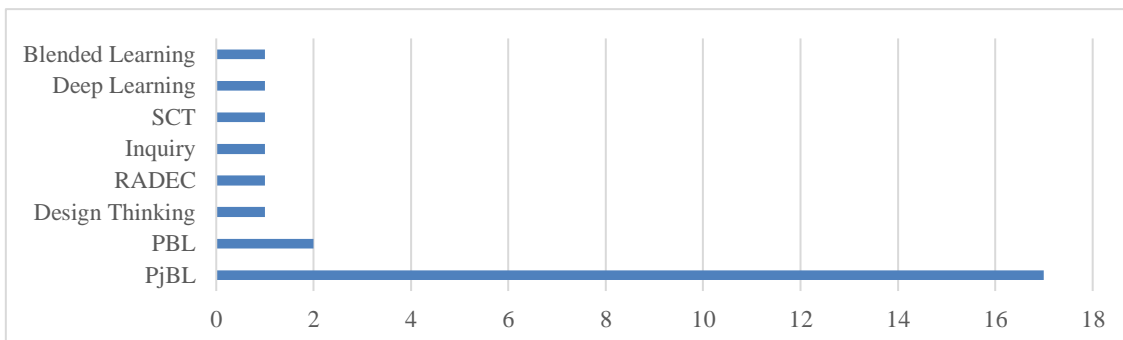


Figure 3. Learning Models

In Figure 4, the application of STEAM in chemistry learning to develop HOTS has been discussed more extensively at the high school level (n=25) than at the university level (n=9), indicating that high school is considered a strategic stage for fostering HOTS. In terms of topics, as illustrated in Figure 5, the majority of research in high school focused on acid-base materials (n=7), followed by polymers (n=3), and other topics such as electrolyte and non-electrolyte solutions, thermochemistry, chemical bonding, buffer solutions, redox, and colligative properties were relatively underexplored. At the university level, research focuses more on the fundamentals and methods, phytochemistry, biodiesel production, and chemical statistics. Several articles also discuss multiple chemistry topics concurrently. Therefore, high school research prioritizes foundational content, while university research contributes to applied contexts. At university, students are not only required to understand basic concepts, but also be able to apply these concepts to solve real-world issues such as complex problems, applied, and research-oriented contexts.

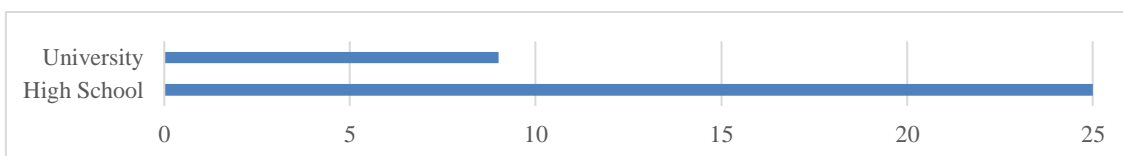


Figure 4. Grouping publications by educational level

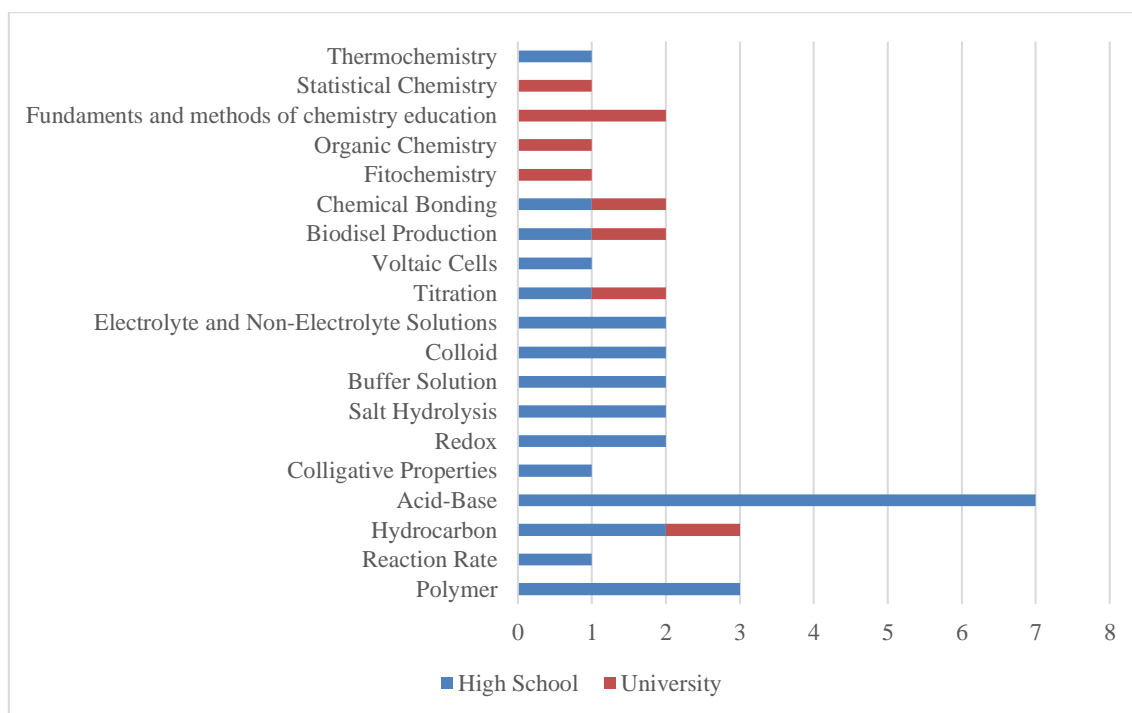


Figure 5. Chemistry topics discussed

RQ2. What types of HOTS can be developed through the STEAM approach in chemistry learning?

Critical Thinking

Table 1. List of Critical Thinking Articles

| Method | Authors, Year | Result |
|-------------|---------------------------|---|
| Activity | (Sequeira & Borges, 2024) | The integration of JAMОВI in chemistry learning with STEAM can be facilitated the cultivation of critical thinking skills. |
| Qualitative | (Ananda et al., 2023) | STEAM-PjBL can be facilitated the cultivation of students' critical thinking skills, encompassing information search, creative interpretation, reasoning, reflection, and regulation. |
| Qualitative | (Ridwan et al., 2022) | The application of STEAM-PjBL is effective in cultivating students' 21st-century skills, which is learning and innovating skills, including critical thinking. |
| Qualitative | (Lisdiana et al., 2023) | The application of STEAM-PjBL is effective in developing students' 21st-century skills, which is learning and innovating skills, including critical thinking. |

| Method | Authors, Year | Result |
|--------------|--|---|
| Qualitative | (Fatimah & Wiji, 2025) | The assessment results show that the STEAM-based Deep Learning approach be able to develop students' critical thinking skills. |
| Qualitative | (Apriliana <i>et al.</i> , 2018) | The implementation of STEAM can develop various students' soft skills, which is critical thinking skills |
| Qualitative | (Tüzün & Eyceyurt Türk, 2019) | STEAM-based learning can enhance students' critical thinking skills. |
| Qualitative | (Rahmawati <i>et al.</i> , 2022) | The application of the STEAM dilemma engages students in-depth learning chemistry while developing their critical reflective social thinking. |
| Qualitative | (Handayani & Nurhamidah, 2024) | The integration of STEAM-PjBL can cultivate various soft skills in students', one of which is critical thinking. |
| Qualitative | (Yuli Rahmawati, Ramadhani, & Afrizal, 2020) | The application of STEAM in chemistry has not shown positive impacts on students' critical thinking skills. |
| Survey | (Mardikaningrum <i>et al.</i> , 2025) | Some teachers believe that the STEAM approach has the potential to strengthen critical thinking. |
| Quantitative | (Rahmadani <i>et al.</i> , 2025) | Integrating STEAM-PBL with local wisdom can enhance students' critical thinking skills. |
| Quantitative | (Muhammad <i>et al.</i> , 2024) | PjBL-STEAM is effective in improving students' critical thinking skills. |
| Quantitative | (Suryaningsih & Ainun Nisa, 2021) | The percentage of science process skills with STEAM-PjBL is in the high category, and critical thinking skills are part of science process skills. |
| Quantitative | (Setyawan <i>et al.</i> , 2023) | The RADEC learning model based on STEAM has a positive influence on students' critical thinking and produces better results compared to the inquiry learning model. |
| Quantitative | (Gusman <i>et al.</i> , 2024) | The STEAM-based learning model with Chemskech has been proven to significantly enhance critical thinking skills. |
| Quantitative | (Sequeira <i>et al.</i> , 2025) | The implementation of STEAM can enhance critical thinking skills, through the activities in chemistry and statistics laboratories, in a meaningful context. |

The integration of the STEAM approach into chemistry learning has the potential to cultivate and strengthen critical thinking, a core soft skill indispensable for students in the 21st century (Apriliana, Ridwan, Hadinugrahaningsih, & Rahmawati, 2018; Handayani & Nurhamidah, 2024; Tüzün & Eyceyurt Türk, 2019). The validity of this assertion is further substantiated by the findings of quantitative studies reinforces this claim, particularly through the application of a STEAM-based Problem-Based Learning (STEAM-PBL) model grounded in local wisdom and the integration of the STEAM-

oriented RADEC framework, both of them have demonstrated measurable gains in students' critical thinking capacities (Rahmadani, Erika, Watulingas, & Kasyfita, 2025; Setyawan, Roshayanti, & Novita, 2023). STEAM-PjBL has also become a dominant line of study, consistently showing positive contributions to students' critical thinking (Ananda, Rahmawati, & Khairi, 2023; Lisdiana, Rahmawati, Ridwan, & Hadinugrahaningsih, 2023; Ridwan, Fatimah, Hadinugrahaningsih, Rahmawati, & Mardiah, 2022; Rusmansyah et al., 2024; Suryaningsih & Ainun Nisa, 2021). In the social scope, the adoption of STEAM-based Deep Learning has been shown to foster students' dispositions toward critical reflection, while the Dilemma-STEAM model in chemistry instruction has provided meaningful learning experiences that stimulate the development of critical reflective social thinking, (Fatihah & Wiji, 2025; Yuli Rahmawati, Taylor, Taylor, Ridwan, & Mardiah, 2022). However, qualitative evidence indicates that the approach is not universally effective, with at least one study reporting no measurable gains in critical thinking, underscoring the need for sustained refinement and contextual adaptation (Yuli Rahmawati et al., 2020).

Student activities grounded in STEAM, such as laboratory work and statistical learning with JAMOV, have been shown the fostering of critical thinking through processes of data representation and interpretation (Crissanto Antonio Sequeira & Borges, 2024; Crissanto António Sequeira, de Souza Júnior, & Borges, 2025). Similarly, the use of Chemsketch has proven effective in enhancing students' critical thinking within the context of chemical visualization (Gusman, Vivit Dania, & Mutiara Dwi Cahyani, 2024). Consistent with these findings, a survey of 40 chemistry teachers in Demak Regency confirmed the perceived relevance of the STEAM approach for strengthening students' critical thinking, thereby underscoring its urgency and value as an innovative strategy for chemistry instruction (Mardikaningrum, Patonah, & Novita, 2025).

Creative Thinking

Table 2. List of creative thinking articles

| Method | Authors, Year | Result |
|--------------|---|--|
| Quantitative | (Nurfadilah & Siswanto, 2020) | Students' creative thinking skills can be enhanced by ESD-based STEAM approach. |
| RnD | (Rr Tasya Noor Nabila & Agus Kamaludin, 2023) | The STEAM-PjBL-based e-worksheet has been tested and received a rating of excellent, indicating its effectiveness in enhancing students' creative thinking skills. |
| Survey | (Mardikaningrum et al., 2025) | ESD-based STEAM has significant potential for further development in enhancing students' creativity. |
| RnD | (Jannah et al., 2024) | The results of the LKS test based on TCOF are categorized as high, indicating that the STEAM-based PjBL LKS model has the potential to teach creativity to students. |
| Qualitative | (Ridwan et al., 2022) | STEAM-PjBL encourages students to develop 21st-century skills, which is creative thinking categorized under Learning and Innovation Skills. |

| Method | Authors, Year | Result |
|---------------------------|-----------------------------------|--|
| Qualitative | (Lisdiana et al., 2023) | The STEAM-PjBL approach can be used as an alternative to improve 21st-century skills, which is creative thinking categorized under Learning and Innovation Skills. |
| RnD | (Norsalehah et al., 2022) | SCT-based STEAM learning tools can enhance students' creative thinking skills. |
| Quantitative | (Suryaningsih & Ainun Nisa, 2021) | STEAM project learning innovations during the learning process can support students' creative thinking skills. |
| Classroom Action Research | (Rahman et al., 2020) | The implementation of STEAM-based PjBL models enhances students' creative thinking in cycle I and cycle II. |
| Qualitative | (Fatihah & Wiji, 2025) | The STEAM-based Deep Learning approach can effectively cultivate the 4C character (Critical Thinking, Creative Thinking, Communication, and Collaboration). |
| Quantitative | (Oktavia et al., 2022) | The application of the PjBL-STEAM has a positive influence on students' creativity, and the higher levels of conceptual understanding tend to demonstrate greater creativity |
| Qualitative | (Apriliana et al., 2018) | The implementation of STEAM can develop various soft skills in students, such as cooperation and creative thinking. |
| Quantitative | (Annisa et al., 2019) | There was a difference in students' creative thinking skills between the pretest and posttest results using the model, where the posttest scores increased. |
| RnD | (Khamhaengpol et al., 2022) | The students' creative thinking was reflected in the biodiesel packaging design and the selection of raw materials. The students' basic science process skills (BSPS) were in the good category. |
| Qualitative | (Tüzün & Eyceyurt Türk, 2019) | The STEAM-based learning process can enhance creativity skills, as evidenced by the results of student learning process evaluations, which identify creativity in students' pop art creations. |
| Quantitative | (Suryaningsih et al., 2023) | The application of the STEAM-PBL approach is effective in developing students' creative thinking skills. |
| RnD | (Hamid et al., 2024) | LKPD qualifies the criteria for effectively improving students' creative thinking skills. |
| Qualitative | (Handayani & Nurhamidah, 2024) | The integration of STEAM-PjBL can develop various soft skills in students, such as responsibility, adaptability, and creative thinking. |

| Method | Authors, Year | Result |
|-------------|----------------------------|---|
| Qualitative | (Sausan & Masbukhin, 2024) | A significant positive correlation between creativity and cognitive academic outcomes is observed, indicating that STEAM Project-Based Learning has the potential to stimulate creative thinking. |
| Survey | (Domenici, 2023) | The students' successfully designed history-based educational projects, demonstrating a high level of creativity. |
| Survey | (Domenici, 2022) | Students are able to design and implement multidisciplinary projects focused on specific chemistry topics by utilizing their knowledge and creativity. |

Students' creative thinking skills can be enhanced by STEAM-ESD approach (Nurfadilah & Siswanto, 2020), supported by the analysis of the potential and challenges of implementing STEAM-based learning showing 90% of teachers believe that the ESD-oriented STEAM approach can enhance students' creativity (Mardikaningrum et al., 2025). Integrated STEAM learning through PjBL can also be an alternative to encourage students development of 21st-century skills, including creative thinking skills (Lisdiana et al., 2023; Ridwan et al., 2022). STEAM implementation also contribute the enhancement of various soft skills, including creative thinking skills (Apriliana et al., 2018; Handayani & Nurhamidah, 2024). Moreover, there is a significant difference in students' creative thinking abilities between the pretest and posttest results after implementation of the STEAM-integrated Project-Based Learning (PjBL) model (Annisa, Effendi, & Damris, 2018). Findings of implementing STEAM-PjBL learning also show a significant positive correlation between students' creativity and their cognitive academic outcomes (Sausan & Masbukhin, 2024).

Various instructional tools integrating the STEAM approach with Project-Based Learning (PjBL) have been developed, including an e-worksheet focused on reaction rate material, which validated results categorized as excellent (Rr Tasya Noor Nabila & Agus Kamaludin, 2023), LKPD on acid-base material demonstrates validity results in the highly valid category (Hamid, Nana, Syahmani, & Rusmansyah, 2024), and LKS on acid-base material tested based on the Teaching for Creativity Observation Form (TCOF) indicator showed high test results (Jannah, Wahyu, & Suryatna, 2024). The development of learning tools using the SCT (Scientific Critical Thinking) model based on the STEAM approach was also carried out, but the results still in the moderate category (Norsalehah, Leny, Rusmansyah, & Sholeha, 2022). STEAM-based learning for preservice chemistry teachers has been implemented through visiting to science museums, resulting in the application of multidisciplinary projects on specific chemistry topics designed by taking advantage of knowledge and creativity (Domenici, 2022, 2023). In a classroom action research employing the PjBL model integrated with the STEAM approach indicated an enhancement in students' creative thinking skills (Rahman, Suharto, & Iriani, 2020).

The innovation of STEAM approach in chemistry learning holds significant potential for further development in enhancing students' creative thinking skills (Mardikaningrum et al., 2025; Oktavia, Haryanto, & Ngatijo, 2022; Suryaningsih & Ainun Nisa, 2021). STEAM-integrated art-based chemistry learning can enhance creative

thinking skills (Fatihah & Wiji, 2025; Suryaningsih, Rahmawanti, & Suciati, 2023; Tüzün & Eyceyurt Türk, 2019). Furthermore, STEAM-based chemistry learning conducted in the laboratory can enhance students' creative thinking skills through the practical application of biodiesel activities (Khamhaengpol, Phewphong, & Chuamchaitrakool, 2022). STEAM-based chemistry learning can improve students' creative thinking skills through the integration of various models and approaches such as Problem Based Learning (PBL), Project Based Learning (PjBL), Deep Learning, Education for Sustainable Development (ESD), and Scientific Critical Thinking (SCT).

Decision Making

Table 3. List of decision making articles

| Method | Authors, Year | Result |
|-------------|--------------------------|--|
| Qualitative | (Rahmawati et al., 2022) | The application of the STEAM dilemma engages students in-depth learning chemistry and develops their collaborative decision-making skills. |

STEAM Dilemma integration that focuses on local environmental issues through project-based activities can enhance students' decision-making skills in chemistry learning (Yuli Rahmawati et al., 2022). Active participation of student in designing and implementing projects encourages them to express ideas, collaborate in teams, and make appropriate decisions in addressing problems encountered. Interaction among students while sharing information provides opportunities to practice listening, consider others' perspectives, and gain additional insights that enrich the decision-making process.

Logic and Reasoning

Table 4. List of Logical reasoning articles

| Method | Authors, Year | Result |
|-------------|-----------------------|--|
| Qualitative | (Ananda et al., 2023) | The application of STEAM-PjBL with Design Thinking can enhance students' Creative Interpretation and Reasoning skills. |

The integration of STEAM-PjBL with Design Thinking has been shown to enhance students' Creative Interpretation and Reasoning skills in achieving conceptual understanding in chemistry learning. Most students reached an advanced or proficient level, as reflected in their ability to formulate conclusions logically, systematically, and validly. These interpretation and reasoning skills constitute an integral component of critical thinking, which can be consistently strengthened through the application of STEAM-PjBL based instructional strategies. (Ananda et al., 2023).

Reflection

Table 5. List of reflection articles

| Method | Authors, Year | Result |
|-------------|-----------------------|---|
| Qualitative | (Ananda et al., 2023) | The application of STEAM-PjBL with Design Thinking can enhance Reflection and Self Regulation skills. |

| Method | Authors, Year | Result |
|-------------|-------------------------------|---|
| Qualitative | (Yuli Rahmawati et al., 2022) | The application of the STEAM Dilemma can foster Values Reflection in deep chemistry learning. |

The implementation of STEAM has been shown to foster students' ability to reflect on values embedded in chemistry. Emphasizing context-based chemistry learning through the application of STEAM-PjBL with Ethical Dilemma tasks can further stimulate students to reflect on these values, thereby rendering the learning process more meaningful (Yuli Rahmawati et al., 2022). Another study on STEAM-PjBL reported that students' reflection and self-regulation skills, covering aspects of reflection, planning, and mindset, were at an advanced level, indicating the development of a more active mindset and the ability to actualize previously untapped potential (Ananda et al., 2023).

Metacognitive

Table 6. List of metacognitive articles

| Method | Authors, Year | Result |
|--------------|--------------------------|---|
| Quantitative | (Ahmar & Azzajjad, 2025) | The integration of STEAM-Gamification has been proven to improve metacognitive thinking skills. |

As an innovative instructional approach, STEAM-based Gamification more than improves students' understanding of chemistry but also strengthens their metacognitive thinking capacities (Ahmar & Azzajjad, 2025). The STEAM-Gamification strategy has been shown to create a more interactive and engaging learning setting, while also encouraging critical thinking and raising students' awareness of the learning methods employed.

Analyze

Table 7. List of analyze articles

| Method | Authors, Year | Result |
|--------------|-----------------------------------|---|
| Quantitative | (Suryaningsih & Ainun Nisa, 2021) | The percentage of science process skills achieved high category through STEAM-PjBL, and analytical thinking is recognized as an integral component of these skills. |

The application of STEAM-PjBL in chemistry learning through the utilize of WhatsApp groups and Instagram has been shown to support students' analytical thinking skills, which constitute an essential aspect of science process skills. Analytical thinking, as part of the scientific disposition, is essential for addressing 21st-century challenges, as it requires mastery of HOTS to generate logical, critical, and systematic solutions (Suryaningsih & Ainun Nisa, 2021).

Evaluation/Judgement

Table 8. List of evaluation articles

| Method | Authors, Year | Result |
|--------|---------------|--------|
|--------|---------------|--------|

| | | |
|-------------|-----------------------|---|
| Qualitative | (Ananda et al., 2023) | The integration of STEAM-PjBL with Design Thinking can support skills in evaluating the credibility of sources. |
|-------------|-----------------------|---|

The integration of STEAM-PjBL with Design Thinking in chemistry learning resulted in advanced achievement in the ability to evaluate the credibility of sources. (Ananda et al., 2023). This was marked by students' ability to synthesize various aspects and sources of information comprehensively, reflecting one of the key indicators of critical thinking skills.

Problem Solving

Table 9. List of problem solving articles

| Method | Authors, Year | Result |
|--------------|-----------------------------------|--|
| Qualitative | (Ridwan et al., 2022) | The application of STEAM-PjBL is effective in developing students' 21st-century skills, which is problem-solving categorized Learning and Innovating skills. |
| Qualitative | (Lisdiana et al., 2023) | The application of STEAM-PjBL is effective in developing students' 21st-century skills, which is problem-solving categorized Learning and Innovating skills |
| Quantitative | (Sequeira et al., 2025) | The laboratory and statistical exercises highlight the importance of STEAM education in enhancing problem-solving abilities by effectively integrating chemistry and statistics within a meaningful context. |
| Quantitative | (Maulina et al., 2024) | STEAM-PjBL learning has a significant positive effect on students' soft skills, including problem-solving. |
| Quantitative | (Suryaningsih & Ainun Nisa, 2021) | The level of science process skills attained through the STEAM-PjBL approach is categorized as high, with problem-solving recognized as an integral component of creative thinking skills |
| RnD | (Syahmani et al., 2023) | The e-module that was developed has been proven effective in improving problem-solving skills among students. |
| RnD | (Syahmani et al., 2025) | The e-module on biodiesel using a STEAM approach and web-based blended learning is suitable for use and capable of improving students' problem-solving skills. |
| Survey | (Mardikaningrum et al., 2025) | The survey results show that the STEAM approach has the potential to enhance students' problem-solving skills. |

The integration of STEAM-PjBL contributes to the development of 21st-century skills, particularly within the domain of Learning and Innovation, which encompasses problem-solving (Lisdiana et al., 2023; Ridwan et al., 2022). Quantitative studies have

demonstrated that STEAM-PjBL has a significant impact on enhancing students' soft skills, especially problem-solving abilities (Maulina et al., 2024). Further evidence indicates that STEAM-PjBL holds a crucial role in strengthening problem-solving skills, which are closely linked to creative thinking (Suryaningsih & Ainun Nisa, 2021).

On the other hand, the development of a STEAM-Inquiry based e-module on phytochemistry (Syahmani et al., 2023) and a Web-based STEAM e-module on biodiesel integrating with Blended Learning Approach (Syahmani et al., 2025) has been reported as highly valid and practical, with proven effectiveness in enhancing students' problem-solving skills. Furthermore, survey findings revealed that integrating STEAM with the concept of Education for Sustainable Development (ESD) holds potential for fostering students' problem-solving abilities by cultivating awareness of contributing to global environmental issues (Mardikaningrum et al., 2025).

■ CONCLUSION

Research trends on the application of the STEAM approach in chemistry learning to develop HOTS have shown progressive development since 2018, with publication intensity experiencing a significant acceleration in 2022 and reaching its peak in 2024. The most frequently examined skills is creative thinking, followed by critical thinking and problem-solving, while other skills such as reflection, decision-making, logical reasoning, and metacognition remain marginal, and the skill of creation has not yet received any attention. This shows a research bias, as creation skills—the highest level of Bloom's taxonomy—remain neglected. Research has been predominantly focused on senior high school rather than higher education, indicating that this stage is considered a crucial phase in the development of HOTS. Turning to chemical topics, the most attention at the senior high school level include acid–base, whereas at the higher education level, research has been more directed toward applicative aspects. In high school emphasizes foundational content, whereas university focuses on applying concepts to applied, and research-oriented contexts.

The development of HOTS can be facilitated through the implementation of STEAM either independently or in integration with various innovative learning models, such as Project-Based Learning (PjBL), Problem-Based Learning (PBL), Design Thinking, Read-Answer-Discuss-Explain and Create (RADEC), Inquiry, Deep Learning, Gamification, and Blended Learning, among which PjBL has been most dominantly applied and proven strategy. In addition, several learning tools that have been developed, such as LKPD, E-LKPD, and E-Modules, have proven effective in supporting the improvement of HOTS underscores the importance of digital learning tools. This confirms that integrating STEAM makes a strategic contribution to strengthening 21st-century competencies in the context of chemistry education. Future research should explore more STEAM's comprehensive role in fostering all types of HOTS.

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