JISE 12 (3) (2023): 262-268

Journal of Innovative Science Education

http://journal.unnes.ac.id/sju/index.php/jise

Review of Fundamental Framework for Reflective Thinking and Practice in Science Education: Implications for Transformative Science Learning Worldwide

Pipih Nurhayati[1] ✉, Ari Widodo[2], Achmad Syamsudin[3]

[1,2] Program of Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
[3]Program of Physics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

Article Info

Article History :
June 2023
Accepted
September 2023
Published
December 2023

Keywords:
Reflective Thinking; Science Learning; Transformative Learning

Abstract

Reflective thinking has a huge contribution in transformative science learning. The primary objective of this study is to establish a fundamental framework for reflective thinking and practice in science education that can contribute to transformative learning worldwide. The study utilized the SPIDER inclusion criteria to select relevant articles from SCOPUS and WoS databases in 2018 up to March 2023, which included sample, phenomenon of interest, design, evaluation, and research type. The PRISMA framework was also used, which consisted of four steps: identification, screening, eligibility, and inclusion. In the end, the study analyzed 52 from 621 articles using Biblioshiny as a tool for analysis. The results indicated that Reflective Practice, International Journal of Science Education, and Education Sciences are the most commonly used sources for research on this topic. Turkey and the USA have shown the highest productivity in terms of research on reflective thinking. The frequency of the term "reflective thinking" has increased steadily over the years, indicating its growing significance in the field of education and research. Several teaching and assessment strategies can play a significant role in facilitating transformative learning by encouraging individuals to solve problems, communicate effectively, exhibit self-confidence, remain engaged, plan and collaborate with others.

✉ correspondence :
Jl. Dr. Setiabudi No.229, Kota Bandung, Jawa Barat 40154, Indonesia
E-mail: pipih.nurhayati@upi.edu

p-ISSN 2252-6412
e-ISSN 2502-4523

INTRODUCTION

The capacity for reflective thinking is essential in science education (Bassachs et al., 2020; García-Carmona, 2021; Vogelsang et al., 2022), as it allows teachers and students to engage with new ideas and approaches and adapt to changing circumstances (Slepcevic-Zach & Stock, 2018; Nazleen et al., 2020; Elsayary, 2021). Encouraging reflective practice inspires students to consistently learn from their encounters, connecting the disconnect between concepts and real-life situations (Bunt & Gouws, 2020; Orcid et al., 2023), and growing as lifelong learners (Elsayary, 2021; Ayaz & Gök, 2022; Kingkaew et al., 2023). Transformative learning is distinguished by a profound change in an individual's perspective, leading to a significant modification in their perception of self, others, and the surrounding world (Fleming, 2018). In the domain of science education, transformative learning assumes a critical function in nurturing students' capacity to challenge their current convictions and achieve a more profound comprehension of scientific principles and their ramifications. Previous literature research has revealed how reflective thinking has been studied in the literature in terms of appropriate approaches, appropriate media or reflective strategies used (Azevedo et al., 2022; Orcid et al., 2023; Yilmaz & Keser, 2016). Currently, there is a need for literature research that shows the interactions and opportunities for reflective thinking skills to be developed in transformative education.

Reflective thinking

In contemporary society, it is expected that individuals possess a diverse range of proficiencies, which include problem-solving, creative thinking, critical thinking, learning to learn, and reflective thinking (e.g Yu et al., 2014; Orakcı, 2021; Sebatana & Dudu, 2022). Out of these skills, reflective thinking is deemed to be the most significant as it represents a high-level thinking skill (Maksimović & Osmanović, 2019; Menon & Azam, 2021; Ayaz & Gök, 2022) because it requires problem recognition, reflection on action in solving a problem and analyzing what has been done well or wrong for further improvements (Onrubia et al., 2022; Orcid et al., 2023). This particular skill demands individuals to consistently reevaluate and adapt their problem-solving strategies to acquire novel ways of gathering information (Maksimović & Osmanović, 2019; Bunt & Gouws, 2020; Ayaz & Gök, 2022) . Hence, it is imperative for academic institutions to incorporate reflective thinking skills into their syllabus, thereby equipping individuals with the ability to become efficient problem-solvers and perpetual learners in the ever-evolving world of tomorrow.

Dewey (1933) first introduced the concept of reflection, defining it as the deliberate and systematic inspection of beliefs, knowledge, and practices using current information and comprehension, and emphasizing its significance as a vital educational objective (Rodgers, 2002; Puig et al., 2020; Orakcı, 2021). While certain scholars perceive reflection as a difficult task that reconstructs previous knowledge and perceptions, others associate it with a dynamic and deliberate investigation of experiences (Wang & Lin, 2008; Stylianides et al., 2013; Allen & Blythe, 2018). Reflective thinking is a systematic problem-solving approach that involves using emotions, thoughts, and knowledge to reach a logical solution (Bassachs et al., 2020; Ronen, 2020; Son & Lee, 2021). Reflective thinking is characterized by individuals acquiring knowledge from their experiences, resolving issues, and enhancing their professional development. (Parmigiani et al., 2019; Daniëls et al., 2020;Sebatana & Dudu, 2022). It is crucial for educational institutions to prioritize the development of reflective thinking skills in their curriculum, as it not only facilitates problem-solving and professional growth but also promotes lifelong learning for students.

Given the paramount importance of reflective thinking, it is imperative to assist students in developing strategies that allow them to apply new knowledge to intricate situations in their day-to-day lives, while also encouraging reflective thinking during the learning process (Postholm, 2018; Cirak Kurt & Yildirim, 2021; Orcid et al., 2023). By doing so, students are better equipped to connect new information with past experiences, think in abstract and conceptual terms, employ specific strategies to tackle novel tasks, and comprehend their own cognitive processes to create efficient learning strategies (Gette & Kryjevskaia, 2019; Erickson et al., 2021). Students with the ability to engage in reflective thinking are conscious of their learning experiences and capable of utilizing this knowledge

to address diverse problem situations, thereby enabling them to handle these situations proficiently (Aslam et al., 2021; Hiscox et al., 2022; Muhammad et al., 2023). Students who have honed their reflective thinking abilities possess the ability to identify and prioritize solutions in various situations, allowing them to make informed decisions and successfully tackle more complex tasks. On the other hand, those who lack reflective skills are prone to failure in critical evaluation, often failing to identify and implement the most appropriate solutions (Gette & Kryjevskaia, 2019; Akpur, 2020; Orcid et al., 2023). In summary, reflective thinking offers students a range of benefits, including improved problem-solving skills, enhanced critical evaluation abilities, and the ability to make informed decisions, ultimately leading to improved academic performance and personal growth.

The acquisition of reflective thinking skills is an essential requirement for students to develop their intellectual capabilities (Ahmed & Schwind, 2018; Chen, 2020; Orcid et al., 2023). Reflective thinking empowers students to achieve better academic performance by comprehensively understanding, organizing, transferring, and evaluating knowledge in problem-solving scenarios, as opposed to solely relying on rote memorization (Swanson, 2010; Draissi et al., 2021; Orcid et al., 2023). Additionally, reflective thinking enables individuals to identify their personal strengths and weaknesses and to develop effective solutions to problems encountered (Mamlok-Naaman & Eilks, 2012; Ho & Smith, 2021; Alt et al., 2022). Extensive research has demonstrated that reflective thinking is instrumental in enhancing students' task performance (Oliveira et al., 2021; Treibergs et al., 2022; Yang et al., 2022). However, previous studies on reflective thinking have been criticized for their limited scope, highlighting the need for further research to establish a fundamental framework for reflective thinking and practice in science education. Therefore, the proposed research on establishing a fundamental framework for reflective thinking and practice in science education will address the limitations of previous studies and provide a more comprehensive understanding of the concept, ultimately contributing to transformative learning.

Reflective practice

There exists a substantial corpus of literature that espouses the benefits of reflective practice for both educational practitioners and pedagogy (Maksimović & Osmanović, 2019; Bassachs et al., 2020; Puig et al., 2020). Much of this literature is built on the seminal work of Schön (1987), who posited that the increasing complexity within professional contexts led to a 'reflective turn' in practice. This reflective turn expanded the goals of education beyond mere content acquisition, to include how teaching and learning can foster learners' informed decision-making, personal growth, and social justice (e.g Burgin, 2020; Halpin et al., 2020; Zach & Ophir, 2020). One of his significant and long-lasting contributions was the identification of two forms of reflection: reflection-on-action (reflecting after the event) and reflection-in-action (reflecting while in the process of doing)(e.g Bassachs et al., 2020; Bunt & Gouws, 2020; Puig et al., 2020). Reflective practice continues to evolve, it is increasingly recognized as an essential component of professional development, promoting self-awareness and critical thinking, and enhancing the quality of teaching and learning.

In accordance with Kolb's (1984) perspective, the act of reflection serves as a catalyst for learners to continuously learn from their experiences, thereby closing the divide between theory and practice and developing themselves as lifelong learners (Elsayary, 2021; Bassachs et al., 2020; Alt et al., 2022;). Reflection is a vital precursor for the transfer of knowledge and skills from the classroom to the workplace. As a solution, they have recommended integrating a reflection tool within the training design to aid in the transfer process (Parmigiani, 2019; Antonio & Developing, 2020; Alt et al., 2022). Reflective practice involves a meticulous review of past events in order to enhance future results (Barham et al., 2019; Kramer, 2018; Wilson, 2008). It encompasses a thorough scrutiny of one's conduct and past experiences for personal growth (Wang & Lin, 2008; Erickson et al., 2021; Menon & Azam, 2021;). The notions of reflexivity and critical reflection are commonly associated with reflective practice (Öztürk, 2020; Tran et al., 2022; Muhammad et al., 2023). Reflexivity pertains to an individual's ability and inclination to exhibit comprehensive self-awareness and reflect on their

position in relation to their environment. On the other hand, critical reflection refers to a profound contemplation that involves recognizing the impact of one's assumptions, and evaluating actions and responsibilities from ethical, moral, and societal perspectives (Holden, 2012; Grice & Franck, 2017; Muhammad et al., 2023). Due to the significance of reflective practice in improving educational achievements and individual development, an increasing demand exists for the creation of an all-encompassing reflective practice framework to provide guidance for educators and learners in applying this technique proficiently in diverse settings.

Transformative learning in science education

According to Mezirow (1987), transformative learning is characterized by a fundamental transformation in an individual's viewpoint, resulting in a substantial alteration in how they perceive themselves, others, and the world around them. This transformation is triggered when an individual encounters a new perspective or experiences that challenge their current beliefs, assumptions, and values (Kitchenham, 2008; Swanson, 2010; Fleming, 2018). Transformative Learning focuses on facilitating critical reflection to transform students' understanding of themselves, their life experiences, and the world around them (Van Velzen, 2015; Hoggan & Kloubert, 2020). In the realm of science education, transformative learning plays a crucial role in fostering students' abilities to question their existing beliefs and to gain a deeper understanding of scientific concepts and their implications (Kramer, 2018; Hoggan & Kloubert, 2020). By engaging in this type of learning, students can develop skills that are essential for success in the modern era, including self-directed learning. Through this approach, science education aims to enable students to internalize scientific principles and apply them in their daily lives.

Transformative learning involves the development of critical thinking skills, which involves the ability to question assumptions and beliefs, analyze arguments, and take action based on acquired knowledge and understanding. Additionally, Transformative Learning emphasizes the importance of reflection on learning experiences and life experiences in general (Kitchenham, 2008; Hoggan & Kloubert, 2020), so that students can gain deeper insights into themselves and the world around them. However, there is a notable scarcity of research and information available on Transformative learning, which highlights the need for further investigation and exploration into this area.

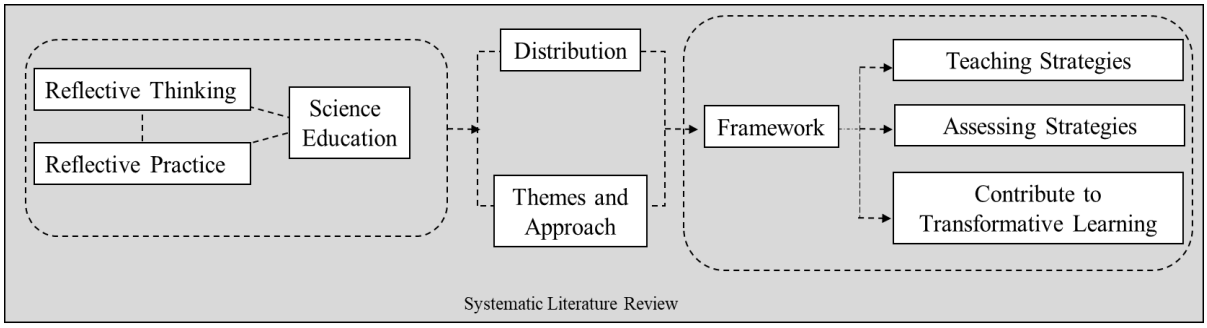

Figure 1. The Process of Conducting a Systematic Literature Review: A Framework

Elaboration is necessary to better understand the limited implementation of reflective thinking and practice in science education, which may be linked to factors such as inadequate teacher training or resources. Examining the specific advantages of using reflective thinking and practice globally would also be beneficial. Considering the potential advantages and obstacles of integrating reflective thinking and practice in science education is crucial. The aim of this study is to establish a fundamental framework for reflective thinking and practice in science education by identifying the teaching and assessment strategies that contribute to transformative learning on a global scale. The research questions are divided into two parts as follows:

RQ 1: What are the research distribution patterns based on the characteristics of content in science

education that incorporates reflective thinking and practice?

RQ 2: What are the common themes and approaches used in the literature to promote transformative learning through reflective thinking and practice in science education?

METHOD

Our study inquiries were derived from the SPIDER framework. The SPIDER framework provides a comprehensive sequence of variables not only about the phenomenon or sample but also uses the type of research and evaluation variables. This framework which comprises Sample, Phenomenon of Interest, Design, Evaluation, and Research type. Refer to Table 1 for detailed information regarding the SPIDER criteria.

Table 1. The selection criteria for the 52 studies included in this systematic review were based on the SPIDER framework

Variables	Inclusion criteria
Sample	✓ Academic professionals (Teacher)
	✓ Science teacher undergraduate and postgraduate students and/or pre-service teacher
	✓ Student with science content (childhood, elementary, high school)
	✓ Respondents from science education
Phenomenon of Interest	✓ Reflective Thinking in science education
	✓ Reflective Practice in science education
Design of the research	✓ Using Questionnaire and Survey
	✓ Conducted with interview
	✓ Conduct a Focus group Discussion
Evaluation of the end of research	✓ Experiences Attitudes/Perceptions
	✓ Ideas Knowledge/Understanding Behaviours
Research type conducted	✓ Qualitative
	✓ Quantitative
	✓ Mixed method

S Sample; PI Phenomenon of Interest; D Design; E Evaluation; R Research type

During March 2023, we conducted a search on the Web of Science and Scopus databases using specific keywords ("reflective thinking" OR "reflective practice" OR "reflective" AND ("science" OR "biology" OR "chemistry" OR "physics")) and text words to identify English-language articles published between 1st January 2018 and 8th March 2023. The search aimed to identify articles with titles related to the definition, analysis, and relationship of reflective thinking and practice in science education. We searched for all selected keywords in the "Article Title" fields of the databases. However, language, document type, and publication year restrictions were applied during the screening process as part of the exclusion criteria.

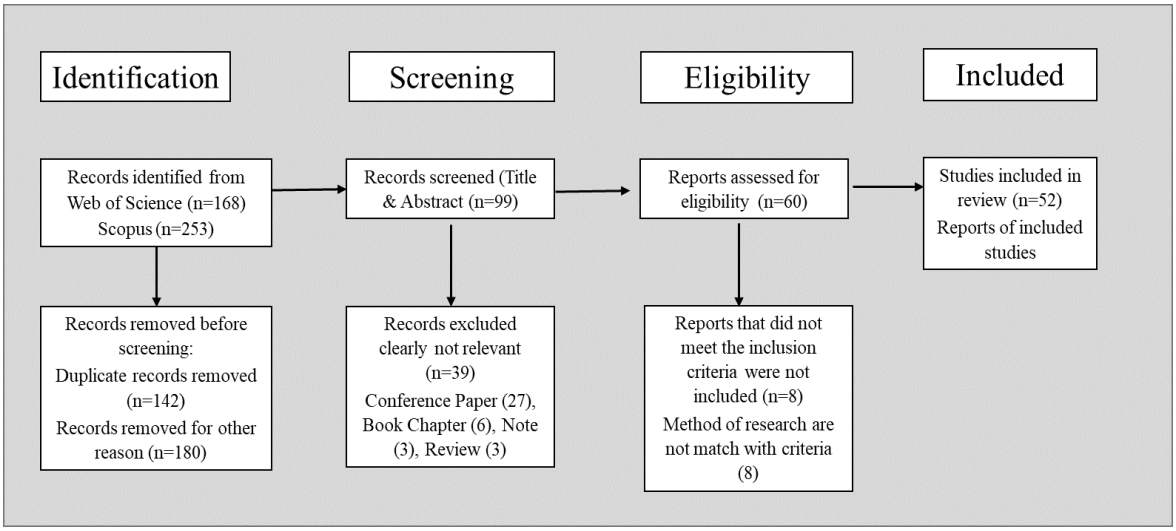

Figure 2. The PRISMA flow diagram was used to document the process of selecting studies for this systematic review

We relied on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) in Figure 2 statement as the basis for the design and report of this systematic review. Given the heterogeneity of study design and data analysis among the studies selected, a qualitative approach was used to synthesize the results. We included original research articles that reported on qualitative, quantitative, or mixed-methods studies exploring the definitions of Reflective Thinking and Reflective Practice in science, biology, chemistry, and physics education, and involved professional and science students as participants. We excluded systematic reviews, meta-analyses, editorials, and commentaries from our search, as well as studies focused in non-science education fields.

PN assessed the titles and abstracts of the studies identified during the initial search and organized relevant articles for further consideration. The full text of the selected articles was then reviewed to determine whether they met the inclusion criteria. To reduce the possibility of research bias, the entire search process was reviewed by PN, AS, and AW. Any research disagreements or disputes were resolved through discussions until a consensus was reached.

Additionally, we carried out bibliometric analysis using biblioshiny® from R Statistical Package. Using the hierarchical clustering strategy, we labeled each keyword as a cluster item and merged clusters with maximum similarity into a large new cluster. Finally, we generated a multiple cluster analysis graphically for review. To avoid research bias, PN, AS, and AW reviewed the entire process and resolved any disagreements through discussions until a consensus was reached.

Table 2. Journal Metrics and Indexing Information

No	Journal	F	%	Indexed by (H Index/SJR 2023)	WoS (H Index/JIF for SSCI or JCI for ESCI 2021)
1	International Journal of Computer-Supported Collaborative Learning	1	1.89	Scopus (Q1/2.69)	WoS (SSCI/5.61)
2	Teaching And Teacher Education	1	1.89	Scopus (Q1/1.95)	WoS (SSCI/3.78)
3	British Journal of Educational Technology	1	1.89	Scopus (Q1/1.87)	WoS (SSCI/5.27)
4	International Journal of STEM Education	1	1.89	Scopus (Q1/1.82)	WoS (SSCI/5.78)
5	Educational Technology Research and Development	2	3.77	Scopus (Q1/1.72)	WoS (SSCI/5.58)
6	Research In Science Education	2	3.77	Scopus (Q1/1.70)	WoS (SSCI/2.47)
7	European Journal of Teacher Education	1	1.89	Scopus (Q1/1.55)	WoS (SSCI/5.22)
8	Thinking Skills and Creativity	1	1.89	Scopus (Q1/1.16)	WoS (SSCI/3.65)
9	International Journal of Science Education	3	5.66	Scopus (Q1/1.15)	WoS (SSCI/2.52)

10	Journal Of Science Education and Technology	3	5.66	Scopus (Q1/1.15)	WoS (SSCI/3.42)
11	Physical Review Physics Education Research	2	3.77	Scopus (Q1/1.08)	WoS (SSCI/2.36)
12	Ecology And Evolution	1	1.89	Scopus (Q1/0.89)	WoS (SCIE/3.17)
13	Chemistry Education Research and Practice	2	3.77	Scopus (Q1/0.85)	WoS (SSCI/3.37)
14	Research In Learning Technology	1	1.89	Scopus (Q1/0.78)	WoS (ESCI/1.12)
15	Techtrends	1	1.89	Scopus (Q1/0.74)	WoS (ESCI/1.18)
16	International Journal of Science Education, Part B	1	1.89	Scopus (Q1/0.72)	WoS (ESCI/1.17)
17	Research In Science & Technological Education	1	1.89	Scopus (Q1/0.71)	WoS (SSCI/1.69)
18	Sustainability	2	3.77	Scopus (Q1/0.66)	WoS (SSCI/3.89)
19	Early Childhood Education Journal	1	1.89	Scopus (Q2/0.64)	WoS (SSCI/1.66)
20	Pedagogy, Culture & Society	1	1.89	Scopus (Q1/0.63)	WoS (ESCI/1.05)
21	Visitor Studies	1	1.89	Scopus (Q1/0.59)	WoS (ESCI/0.35)
22	EURASIA Journal of Mathematics, Science and Technology Education	1	1.89	Scopus (Q2/ 0.57)	
23	Education Sciences	3	5.66	Scopus (Q2/0.52)	WoS (ESCI/1.21)
24	Reflective Practice	4	7.55	Scopus (Q1/0.52)	WoS (ESCI/0.70)
25	Current Psychology	1	1.89	Scopus (Q2/0.51)	WoS (SSCI/2.38)
26	American Journal of Physiology	1	1.89	Scopus (Q2/0.50)	WoS (SSCI/2.39)
27	International Journal of Instruction	1	1.89	Scopus (Q2/0.50)	WoS (ESCI/0.69)
28	Turkish Online Journal of Distance Education-TOJDE	1	1.89	Scopus (Q2/0.41)	WoS (ESCI/0.73)
29	Sage Open	1	1.89	Scopus (Q2/0.40)	WoS (SSCI/2.03)
30	Pedagogy In Health Promotion	1	1.89	Scopus (Q3/0.30)	WoS (ESCI/-)
31	African Journal of Research in Mathematics, Science and Technology Education	1	1.89	Scopus (Q3/0.28)	WoS (ESCI/0.23)
32	International Journal of Innovation in Science and Mathematics Education	1	1.89	Scopus (Q3/0.25)	-
33	International Journal of Evaluation and Research in Education (IJERE)	1	1.89	Scopus (Q3/0.24)	-
34	International Journal of Learning, Teaching and Educational Research	3	5.66	Scopus (Q3/0.23)	-
Total		52	100		

The Table 2 shows the number of articles and the percentage of each source that you have reviewed. It is interesting to note that Reflective Practice and had the highest number of articles at 7.55% followed by International Journal of Science Education and Education Sciences at 5.66% each. Additionally, Educational Technology Research and Development, International Journal of Learning, Teaching and Educational Research, Journal of Science Teacher Education, Physical Review Physics Education Research, and Research in Science Education each had 2 articles reviewed, accounting for 3.77% each. Finally, Advances in Physiology Education and African Journal of Research in Mathematics, Science and Technology Education each had one article reviewed, accounting for 1.89% each.

RESULT AND DISCUSSION

Research Question 1: What are the research distribution patterns based on the characteristics of content in science education that incorporates reflective thinking and practice?

This section of the scientific report analyzes the distribution of research based on the characteristics of the content. The aim is to investigate trends of publications related to reflective thinking in science education, examining various factors such as year, country, research methodology, and level of participants. The analysis aims to

provide a deeper understanding of the current state of research on this topic and identify potential gaps or areas for future exploration.

The distribution of research based on year of publication

The Figure 3 provides information regarding the number of articles that were chosen for publication between 2018 and 2023. The total number of articles selected over the six-year period was 52. In the year 2018, only four articles were selected for publication, which accounted for roughly 7.7% of the total articles selected. The subsequent year, 2019, witnessed the highest number of articles being selected, with a total of 13 articles, representing around 25% of the total. In 2020, the number of articles selected slightly declined to 12, constituting 23.1% of the total. The year 2021 witnessed a selection of 9 articles, which is equivalent to 17.3% of the total. In 2022, the number of selected articles increased to 11, representing approximately 21.2% of the total. Lastly, in 2023, only three articles were selected for publication, accounting for approximately 5.8% of the total. Overall, the data highlights fluctuations in the number of articles selected for publication each year. However, it suggests that the year 2019 had the highest number of articles selected, while the year 2023 had the lowest.

Figure 3. Research based on year of publication distribution

Countries of publication distribution

Based on the analysis provided in **Table 3** and **Figure 3**, it appears that Turkey and the USA are the most productive countries in terms of research on reflective thinking in science education, with both countries having a significant increase in the number of articles published over the years. In Turkey, the number of articles on reflective thinking has been steadily increasing, with 1 article in 2018 and 7 articles projected in 2023. Similarly, the USA has also shown a significant increase in the number of articles published, from 1 in 2018 to 12 projected in 2023. Australia and Sweden are also countries that have been productive in this area, with both countries having a consistent number of articles published over the years.

Table 3. Authorship by Country

No	Country	Author
1	Australia	(Lebedev & Sharma, 2019; Eppler et al., 2021; Hiscox et al., 2022)
2	Canada	(Ho & Smith, 2021; Oliveira et al., 2021; Ezezika & Johnston, 2022)
3	China	(Chen, 2020; Draissi et al., 2021; Guo et al., 2022; Yang et al., 2022; Muhammad et al., 2023)
4	Finlandia	(Ketonen & Henrik, 2023)
5	German	(Kulgemeyer et al., 2021; Vogelsang et al., 2022)
6	Hong Kong	(Lin et al., 2018)
7	Indonesia	(Kurniawan et al., 2019; Rosmiati et al., 2020)
8	Saudi Arabia	(Bawaneh et al., 2020; Elsayary, 2021)
9	Israel	(Dwolatzky et al., 2021)
10	Italy	(Parmigiani et al., 2019)
11	Morocco	(Bassachs et al., 2020)
12	Pakistan	(Aslam et al., 2021)
13	Qatar	(Barham et al., 2019)
14	South Africa	(Woolway et al., 2019)
15	Spain	(Clarà et al., 2019)

16	Sweden	(Berg & Orraryd, 2019; Karlström et al., 2019; Walan, 2020; Williams, 2020)
17	Switzerland	(Grant et al., 2019)
18	Taiwan	(Cheng et al., 2019)
19	Turkey	(Alan & Erdoğan, 2018; Akpur, 2020; Cirak Kurt & Yildirim, 2021; Kılıç, 2022; Ayaz & Gök, 2022; Sarı et al., 2022; Orcid et al., 2023)
20	UK	(Archer et al., 2022)
21	USA	(Mccollough et al., 2019; Hong, 2019; Gette & Kryjevskaia, 2019; Halpin et al., 2020; Burgin, 2020; Quarderer & Mcdermott, 2020; Leopold & Smith, 2020; Menon & Azam, 2021; Naidoo et al., 2021; Tran et al., 2022; Treibergs et al., 2022)

On the other hand, China and Canada have had a slower rate of publication in this area. Overall, this analysis of Figure 4 suggests that Turkey and the USA are leading the way in research on reflective thinking, while Australia and Sweden are also contributing significantly to this area of research.

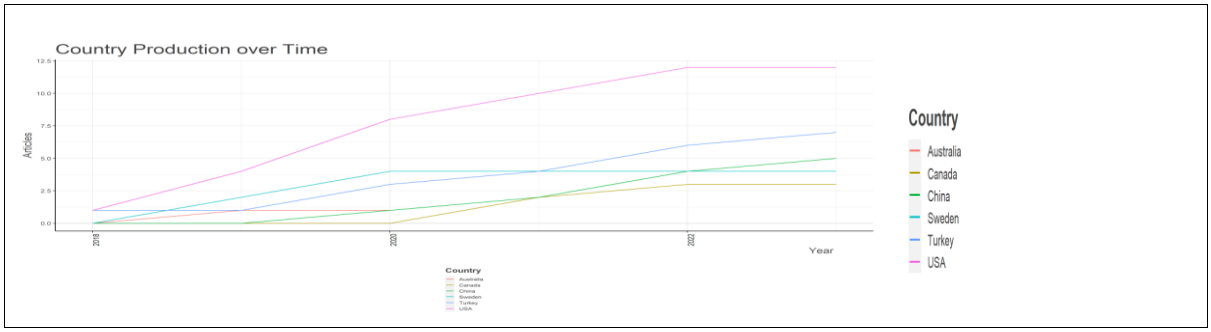

Figure 4. Country production over time

Based on the findings of this analysis, there is a great opportunity for researchers from China and Canada to contribute to the growing body of literature on reflective thinking in science education.

Methodology distribution of the research of reflecttive thinking

The Table 4 delineates the research methodology adopted in a study, detailing the frequency and percentage of use for each approach. It is discernible from the data that a preponderant proportion of the studies (38.46%) espoused a quantitative research approach. This method involves the collection and scrutiny of numerical data to discern patterns and trends. Conversely, 36.54% of the studies adopted a qualitative research approach, which accentuates the collection and analysis of non-numerical data, like opinions and experiences, to comprehend phenomena.

Table 4. Research Methodology Distribution

No	Research Approach	f	%
1	Quantitative	20	38.46
	Correlational	6	
	Experimental Design	4	
	Quasi-Experimental Design	2	
	A Two-Factor Experimental Design	1	
	Pretest-Posttest Control Group	1	
	Descriptive Analytical	1	
	Comparative Design	2	
	Action Research	1	
	Nan	2	
2	Qualitative	19	36.54
	Thematic Content Analysis	4	
	Content Analysis	3	
	A Time-Series Analysis	1	

	Interpretive Approach	1	
	A Structured Analysis/ Categorization	1	
	Analytic Framework Of Practical Epistemology Analysis (PEA)	1	
	Triangulation Analysis	1	
	Reflective Cycle Analysis Was	1	
	In-Depth Analysis	1	
	Descriptive Analysis	1	
	Critical Discourse Analysis	1	
	Comparative Analysis	1	
	Nan	2	
3	Mixed Methods	13	25.00
	Sequential Design	1	
	Exploratory Sequential Design	1	
	Explanatory Squential Design	2	
	Multistrand Design	1	
	Triangulation Design	3	
	Nan	5	
		52	100.00

Finally, 25% of the studies implemented a mixed methods research approach, which amalgamates both quantitative and qualitative techniques to acquire a more holistic understanding of the research topic. The adoption of multiple research approaches enables researchers to investigate a research question from diverse vantage points, heightening the robustness and credibility of the study's conclusions.

The distribution of research based on level of participants of publication

Chart displays educational levels of study's participants, classified into levels and sub-levels with frequency and proportion. Majority in undergraduate programs (47.17%). Majority of undergraduates in 3rd and 4th years (20.75%). Additionally, 3 in graduate programs, 1 from junior/senior high, 3 categorized arbitrarily. eight didn't indicate their level. Table displays 2 primary school instructors and 8 junior high school educators. Finally, 1 falls under "others" category (1.89%). Data offers significant insights into study's participants' educational background, critical to consider when interpreting findings.

Tabel 5. Distribution of Research Participants by Level

Level Of Participant of The Research			f	%
Student	Kindergarten		1	1.89
	Primary School		2	3.77
	Middle School		5	9.43
	High School		5	9.43
	Undergraduate		25	47.17
	First year	1		
	Second year	3		
	Third year	5		
	Fourth year	5		
	Random	3		
	Nan	8		
	Graduate		3	5.66
	Middle and High School		1	1.89
Teacher	Primary School		2	3.77
	Middle School		8	15.09
Others			1	1.89
			78	100

Research Question 2: What are the common themes and approaches used in the literature to promote transformative learning through reflective thinking and practice in science education?

In this section, we analyzed the common themes and approaches used in the literature to promote transformative learning through reflective thinking and practice in science education. We used visualizations such as a graph based on keyword frequency, a two-field chart, and a treemap, which were obtained from the analysis of 52 articles using the biblioshiny application. Based on these visualizations, we conducted an analysis of the most frequently occurring themes that had a strong connection with reflective thinking. We then interpreted the data in the discussion section.

The Figure 5 is a visualization that can be used to show how the frequency of a keyword in scientific publications changes over time. The interpretation of this visualization depends on the selected keyword and the time frame analyzed. In this visualization, the horizontal axis represents time, while the vertical axis shows the frequency of the keyword in scientific publications. By looking at the upward or downward trend on the graph, we can identify changes in the popularity of the keyword.

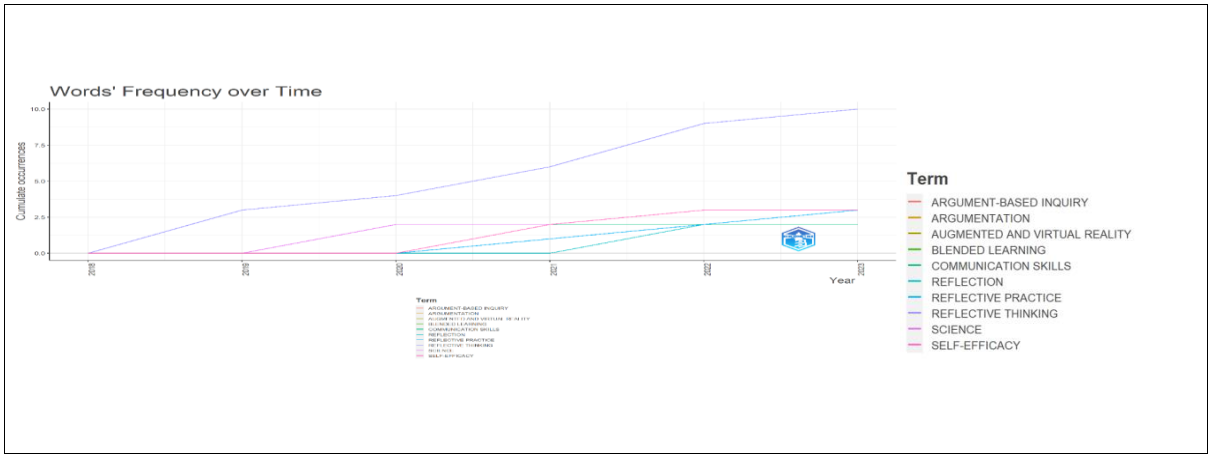

Figure 5. Word Frequency of Keyword over Time

In 2019, "reflective thinking" appeared three times, but its frequency increased steadily, reaching ten occurrences in 2023. This observation indicates that reflective thinking has gained significance and is extensively discussed in the context of science education or research. Additionally, it is noteworthy that words such as "blended learning" and "self-efficacy" have also witnessed an escalation in their frequency of occurrence over the years, albeit not as prominently as the growth witnessed in the term "reflective thinking." Conversely, "reflection" and "reflective practice" experienced a modest hike in the initial years and remained relatively stable in the later years.

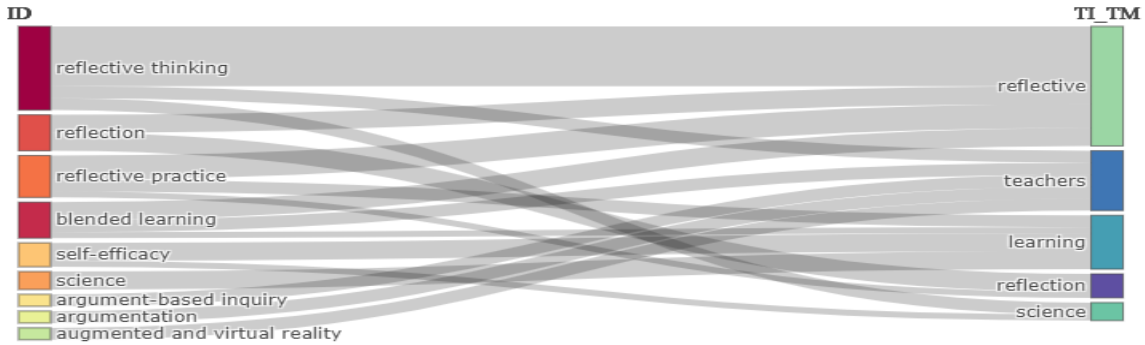

Figure 6. Keyword and Title connected with Three-Field Plot Visualization

Based on further analysis, visualization was done using a three-field plot. Figure 6 shows the visualization results of the relationship between frequently occurring keywords and titles.

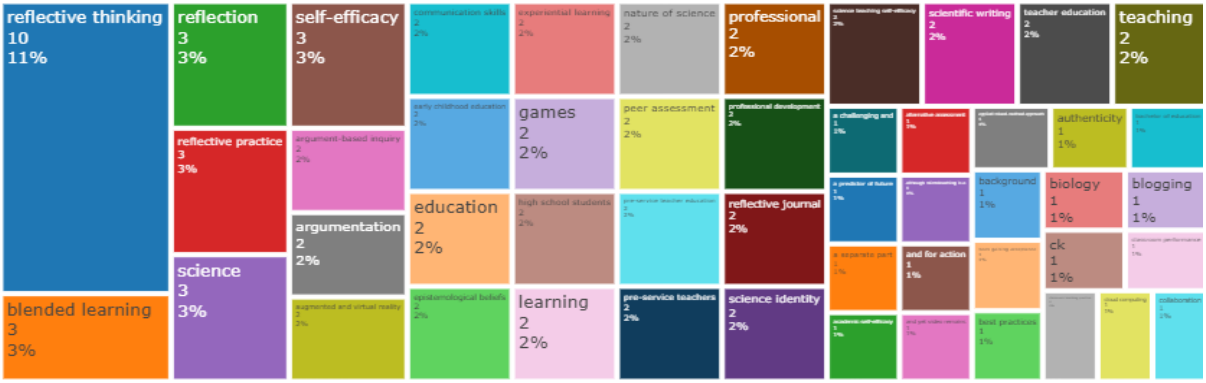

Figure 7. Treemap of term in 52 articles

In Figure 7, it is evident that reflective thinking is the term with the highest frequency of occurrence, at 10 (11%). This indicates that reflective thinking is the main topic. In addition to reflective thinking, there are several other terms that have a fairly high frequency of occurrence, namely blended learning, reflection, reflective practice, science, and self-efficacy, all of which have a frequency of 3 (3%). These terms are also important in the context of reflective research on Science education.

Furthermore, there are many terms with a frequency of 2 (2%) occurrence, such as argument-based inquiry, argumentation, augmented and virtual reality, communication skills, early childhood education, education, epistemological beliefs, experiential learning, games, high school students, learning, nature of science, peer assessment, pre-service teacher education, pre-service teachers, professional development, reflective journal, science identity, science teaching self-efficacy, scientific writing, teacher education, and teaching. In addition, there are several other terms with a lower frequency of occurrence compared to the previous ones, which could still be considered crucial topics for reflective research in Science education. Meanwhile, many other terms with only a 1% frequency of occurrence also appear in the raw treemap data. Even though they may still be relevant to the context of education and research, their frequency of occurrence is not significant enough to be the primary focus of discussion

Our systematic review generated three main themes;

1. Teaching strategies include tools of reflection (Archer et al., 2022; Bunt & Gouws, 2020; Chen, 2020; Cheng et al., 2019; Cirak Kurt & Yildirim, 2021; Draissi et al., 2021; Elsayary, 2021; Eppler et al., 2021; Guo et al., 2022; Halpin et al., 2020; Ketonen & Henrik, 2023; Kulgemeyer et al., 2021; Muhammad et al., 2023; Orcid et al., 2023; Parmin, 2019; Treibergs et al., 2022; Vogelsang et al., 2022; Williams, 2020; Yang et al., 2022; Zach & Ophir, 2020).
2. Assesing strategies (Aslam et al., 2021; Ayaz & Gök, 2022; Bassachs et al., 2020; Bawaneh et al., 2020; Eppler et al., 2021; Hiscox et al., 2022; Ho & Smith, 2021; Parmin, 2019; Puig et al., 2020; Quarderer & Mcdermott, 2020; Rosmiati et al., 2020; Yang et al., 2022).
3. Contribute to transformative learning (Ayaz & Gök, 2022; Burgin, 2020; Cirak Kurt & Yildirim, 2021; Clarà et al., 2019; Draissi et al., 2021; Eppler et al., 2021; Hiscox et al., 2022; Hong, 2019; Karlström et al., 2019; Kurniawan et al., 2019; Lebedev & Sharma, 2019; Menon & Azam, 2021; Muhammad et al., 2023; Naidoo et al., 2021; Oliveira et al., 2021; Orcid et al., 2023; Puig et al., 2020; Vogelsang et al., 2022; Woolway et al., 2019; Yang et al., 2022).

Implementation of reflective thinking and practice in science education is limited and inconsistent. Most science teachers are unfamiliar with the concept and integrating it into their teaching. Therefore, a literature review study is necessary to identify characteristics. This study should analyze content by year, publication type, countries implementing it, research approach, educational stage, and science content. Results can develop a comprehensive framework for implementation, benefiting students worldwide.

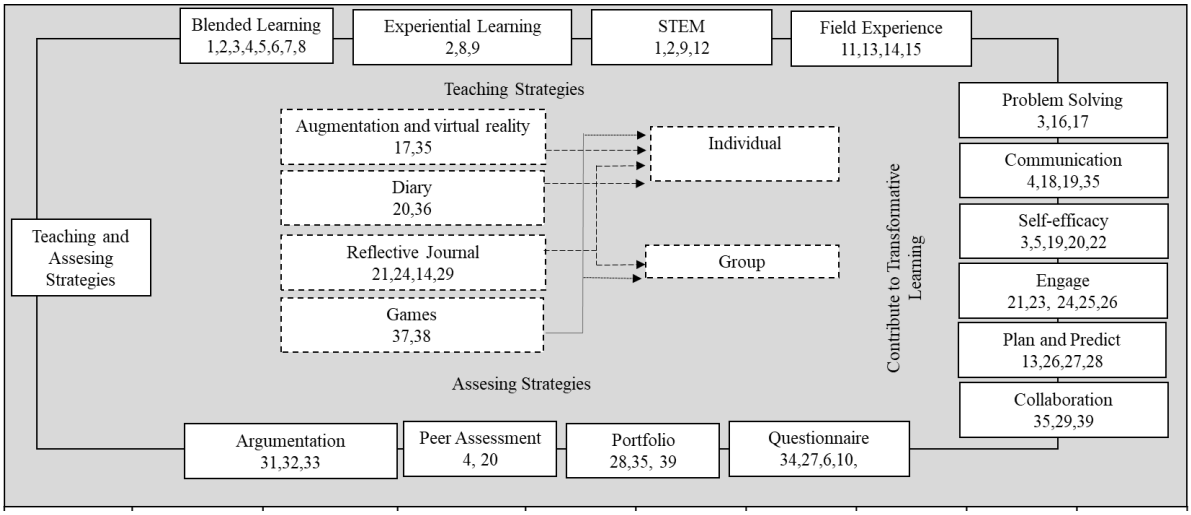

Figure 8. Key aspects that have emerged in this area of research include teaching strategies, assessment strategies, and contributions to transformative learning

The analysis of data suggests that reflective thinking is a highly significant topic in the field of science education research. Reflective Practice, International Journal of Science Education, and Education Sciences are the most commonly used sources for research on this topic. Turkey and the USA have shown the highest productivity in terms of research on reflective thinking, while Australia and Sweden are also contributing significantly. There has been a steady increase in the frequency of occurrence of the term "reflective thinking" over the years, indicating its growing importance in educational research. The raw treemap data reveals that reflective thinking is the primary topic of discussion, followed by blended learning, reflection, reflective practice, science, and self-efficacy, all of which are crucial for reflective research in science education. This analysis highlights the significance of reflective thinking as a learning method and suggests potential topics for future research and educational development.

In the context of reflective thinking in science education, a systematic review can help identify the fundamental aspects that contribute to effective implementation. In the Figure 8 some of the key aspects that have emerged in this area of research include teaching strategies, assessment strategies, and contributions to transformative learning.

Teaching strategies such as blended learning, experiential learning, STEM, and field experience have been identified as important factors in promoting reflective thinking in science education. These resources can be utilised in blended learning to accommodate the learning requirements of students with customised and adaptable teaching approaches (Orcid et al., 2023). Blended learning has the potential to foster a participatory, interactive and captivating learning environment, by providing better accessibility, instructional efficacy and adaptability (Eppler et al., 2021). Moreover, students' involvement and sense of belonging can be augmented when they are willing to employ information and communication technology (ICT) tools in blended learning (Cheng et al., 2019; Ketonen & Henrik, 2023). Integrating transformative and experiential learning approaches in program design and evaluation can facilitate tangible learning outcomes (Elsayary, 2021; Halpin et al., 2020; Kingkaew et al., 2023). This learning environment challenges students to move beyond their comfort zone of traditional face-to-face instruction and engage in online learning while applying the principles of experiential learning to achieve transformative outcomes (Elsayary, 2021; Muhammad et al., 2023). Encourage reflective journaling as a means to support STEM students from diverse racial backgrounds in building strong connections between their life experiences and their studies in science, technology, engineering, and mathematics (Barth-cohen et al., 2018; Tran et al., 2022).

Assessment strategies are also important in promoting reflective thinking in science education. Argumentation, peer assessment, portfolio

assessment, and questionnaires are some of the assessment strategies that have been found to be effective. Argumentation involves constructing and defending arguments based on evidence, which can help students develop critical thinking skills (Barth-cohen et al., 2018; Bassachs et al., 2020; Ho & Smith, 2021). Peer assessment, where students evaluate each other's work, can help promote self-reflection and peer feedback (Muhammad et al., 2023).

Transformative learning refers to the process of a person altering their thought process and perspective on themselves and the world they live in (e.g Elsayary, 2021; Eppler et al., 2021). Reflective thinking can play a significant role in facilitating transformative learning by encouraging individuals to solve problems, communicate effectively, exhibit self-confidence, remain engaged, plan ahead and collaborate with others. These proficiencies are vital for thriving in the modern era and can assist learners in preparing themselves for forthcoming obstacles.

CONCLUSION

The research distribution patterns based on the characteristics of content in science education that incorporates reflective thinking and practice is as follows, 2019 was the year when the most publications were found on the term reflective thinking and it is still increasing. The most contributing countries are Canada and China. Methods that are widely used are quantitative and qualitative rather than mixed methods. The common themes and approaches used in the literature to promote transformative learning through reflective thinking and practice in science education teaching strategies such as blended learning, experiential learning, STEM, and field experience, assessment strategies such as argumentation, peer assessment, portfolio assessment, and questionnaires, and contributions to transformative learning such as problem-solving, communication, self-efficacy, engagement, planning and prediction, and collaboration.

REFERENCES

Akpur, U. (2020). Critical , Re fl ective , Creative Thinking and Their Re fl ections on Academic Achievement U ğ ur Akpur. *Thinking Skills and Creativity*, *37*(May). https://doi.org/10.1016/j.tsc.2020.100683

Alan, Ü., & Erdoğan, S. (2018). Of Course Scientists Haven ' t Seen Dinosaurs on the Beach : Turkish Kindergartners ' Developing Understanding of the Nature of Science Through Explicit – Reflective Instruction. *Early Childhood Education Journal*, *46*(6), 695–706. https://doi.org/10.1007/s10643-018-0892-z

Allen, D., & Blythe, T. (2018). Aesthetics of Facilitation: Cultivating Teacher Leadership. *International Journal of Teacher Leadership*, *9*(2), 48–68.

Alt, D., Raichel, N., & Naamati-Schneider, L. (2022). Higher Education Students' Reflective Journal Writing and Lifelong Learning Skills: Insights From an Exploratory Sequential Study. *Frontiers in Psychology*, *12*(January). https://doi.org/10.3389/fpsyg.2021.707168

Antonio, R. P., & Developing, R. P. (2020). *Developing Students ' Reflective Thinking Skills in a Metacognitive and Argument- Driven Learning Environment Developing Students ' Reflective Thinking Skills in a Metacognitive and Argument-Driven Learning Environment*.

Archer, L., Godec, S., Patel, U., Dawson, E., & Calabrese Barton, A. (2022). 'It really has made me think': Exploring how informal STEM learning practitioners developed critical reflective practice for social justice using the Equity Compass tool. *Pedagogy, Culture and Society*, *00*(00), 1–23. https://doi.org/10.1080/14681366.2022.2159504

Aslam, S., Hali, A. U., Zhang, B., & Saleem, A. (2021). The Teacher Education Program ' s Impact on Preservice Teachers ' Reflective Thinking in Pakistan. *SAGE Open*, *199*. https://doi.org/10.1177/21582440211055724

Azevedo, E. L., Araujo, R. F., & Mesquita, I. R. (2022). The development of reflective skills in physical education teacher education: a systematic review. *Retos*, *46*, 162–178. https://doi.org/10.47197/retos.v46.94080

Ayaz, M., & Gök, B. (2022). The effect of e-portfolio application on reflective thinking and

learning motivation of primary school teacher candidates. *Current Psychology*.

Barham, A. I., Mohammad, E. G., & Miqdadi, R. (2019). Reflective journal writing and classroom performance: Improvement and correlation among pre-service mathematics and science teachers. In *International Journal of Learning, Teaching and Educational Research* (Vol. 18, Issue 11, pp. 348–369). https://doi.org/10.26803/ijlter.18.11.21

Bassachs, M., Cañabate, D., Nogué, L., Serra, T., Bubnys, R., & Colomer, J. (2020). Fostering critical reflection in primary education through STEAM approaches. *Education Sciences*, *10*(12), 1–14. https://doi.org/10.3390/educsci10120384

Bawaneh, A. K., Moumene, A. B. H., & Aldalalah, O. (2020). Gauging the level of reflective teaching practices among science teachers. *International Journal of Instruction*, *13*(1), 695–712. https://doi.org/10.29333/iji.2020.13145a

Berg, A., & Orraryd, D. (2019). Research and Practice Representational challenges in animated chemistry : self-generated animations as a means processes in laboratory exercises. *Chemistry Education Research and Practice*. https://doi.org/10.1039/c8rp00288f

Bunt, B., & Gouws, G. (2020). Using an artificial life simulation to enhance reflective critical thinking among student teachers. *Smart Learning Environments*, *6*.

Burgin, S. R. (2020). A three-dimensional conceptualization of authentic inquiry-based practices: a reflective tool for science educators. *International Journal of Science Education*, *42*(9), 1465–1484. https://doi.org/10.1080/09500693.2020.1766152

Chen, C. H. (2020). Impacts of augmented reality and a digital game on students ' science learning with reflection prompts in multimedia learning. *Educational Technology Research and Development*, *68*(6), 3057–3076. https://doi.org/10.1007/s11423-020-09834-w

Cheng, S., Hwang, G., & Chen, C. (2019). *From reflective observation to active learning: A mobile experiential learning approach for environmental science education*. *50*(5), 2251–2270. https://doi.org/10.1111/bjet.12845

Cirak Kurt, S., & Yildirim, I. (2021). The effects of blogging on pre-service teachers' reflective thinking and self-efficacy. *Reflective Practice*, *22*(2), 233–249. https://doi.org/10.1080/14623943.2021.1879772

Clarà, M., Mauri, T., Colomina, R., & Onrubia, J. (2019). Supporting collaborative reflection in teacher education : a case study. *European Journal of Teacher Education*, *9768*. https://doi.org/10.1080/02619768.2019.1576626

Daniëls, E., Hondeghem, A., & Heystek, J. (2020). Exploring the outcomes of group reflective learning for school leaders. *Reflective Practice*, *21*(5), 604–618. https://doi.org/10.1080/14623943.2020.1784865

Dewey, J. (1933). *How We Think. A Restatement of the Relation of Reflective Thinking to the Educative Process*. D. C. Heath and Company. https://opus4.kobv.de/opus4-Fromm/frontdoor/index/index/docId/7969

Draissi, Z., BaoHui, Z., & ZhanYong, Q. (2021). Reflective journals: enhancing doctoral students' engagement. *Reflective Practice*, *22*(3), 381–399. https://doi.org/10.1080/14623943.2021.1893166

Dwolatzky, N., Tischler, C., & Assaraf, O. B. (2021). The Value of Identifying a Gap in a Reflective Professional Development Program for Informal Science Educators in a Zoo. *Visitor Studies*, *0*(0), 1–17. https://doi.org/10.1080/10645578.2021.1930466

Elsayary, A. (2021). Using a Reflective Practice Model to Teach STEM Education in a Blended Learning Environment. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(2).

Eppler, E., Filgueira, L., Meyer, J., Serowy, S., Link, K., & Pauk, B. (2021). Enhancing Scientific Communication Skills : a Real-World Simulation in a Tertiary-Level Life Science Class Using E-Learning Technology in Biomedical Literature Perception ,

Reflective Review Writing on a Clinical Issue , and Self and Peer Assessments. *Research in Science Education*, 277–299.

Erickson, M., Wattiaux, M. A., & Marks, D. (2021). *Brief , Written Reflections Improve Interest of Introductory Animal Science Undergraduates*. 0–10. https://doi.org/10.1187/cbe.20-08-0164

Ezezika, O., & Johnston, N. (2022). Development and Implementation of a Reflective Writing Assignment for Undergraduate Students in a Large Public Health Biology Course. *Pedagogy in Health Promotion*. https://doi.org/10.1177/23733799211069993

Fleming, T. (2018). Critical Theory and Transformative Learning. *International Journal of Adult Vocational Education and Technology*, *9*(3), 1–13. https://doi.org/10.4018/ijavet.2018070101

García-Carmona, A. (2021). Learning about the nature of science through the critical and reflective reading of news on the COVID-19 pandemic. *Cultural Studies of Science Education*, *16*(4), 1015–1028. https://doi.org/10.1007/s11422-021-10092-2

Gette, C. R., & Kryjevskaia, M. (2019). Establishing a relationship between student cognitive reflection skills and performance on physics questions that elicit strong intuitive responses. *Physical Review Physics Education Research*, *15*(1), 10118. https://doi.org/10.1103/PhysRevPhysEducRes.15.010118

Grant, M., Gilgen, A. K., & Buchmann, N. (2019). *The Rich Picture Method : A Simple Tool for Reflective Teaching and Learning about Sustainable Food Systems*.

Grice, M., & Franck, O. (2017). Conceptions of ethical competence in relation to action readiness in Education for Sustainable Development. *Reflective Practice*, *18*(2), 256–267. https://doi.org/10.1080/14623943.2016.1269001

Guo, X., Hao, X., Deng, W., Ji, X., Xiang, S., & Hu, W. (2022). The relationship between epistemological beliefs , reflective thinking , and science identity : a structural equation modeling analysis. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-022-00355-x

Halpin, P. A., Donahue, A. E., & Johnson, K. M. S. (2020). Undergraduate biological sciences and biotechnology students' reflective essays focus on descriptive details of experiential learning experiences. *Advances in Physiology Education*, *44*(1), 99–103. https://doi.org/10.1152/ADVAN.00144.2019

Hiscox, T. J., Papakonstantinou, T., & Rayner, G. M. (2022). Written Reflection Influences Science Students ' Perceptions of Their Own and Their Peers ' Teamwork and Related Employability Skills. *International Journal of Innovation in Science and Mathematics Education*, *30*(4), 15–28.

Ho, K., & Smith, S. R. (2021). *Research and Practice post-secondary students within a lab-based community service learning water project*. https://doi.org/10.1039/d1rp00123j

Hoggan, C., & Kloubert, T. (2020). Transformative Learning in Theory and Practice. *Adult Education Quarterly*, *70*(3), 295–307. https://doi.org/10.1177/0741713620918510

Holden, M. M. (2012). Using critically reflective practice when implementing ethical and sensitive spiritual frameworks in social work practice. *Reflective Practice*, *13*(1), 65–76. https://doi.org/10.1080/14623943.2011.626021

Hong, Y. (2019). Relationship between student designers ' reflective thinking and their design performance in bioengineering project : exploring reflection patterns between high and low. *Educational Technology Research and Development*, *67*(2), 337–360. https://doi.org/10.1007/s11423-018-9618-6

Karlström, M., Hamza, K., Karlström, M., & Hamza, K. (2019). Preservice Science Teachers ' Opportunities for Learning Through Reflection When Planning a Microteaching Unit Preservice Science Teachers ' Opportunities for Learning Through Re fl ection When Planning a Microteaching Unit. *Journal of Science Teacher Education*, *30*(1), 44–62. https://doi.org/10.1080/1046560X.2018.1531345

Ketonen, L., & Henrik, J. (2023). Supporting student teachers ' re fl ection through assessment : The case of re fl ective podcasts. *Teaching and Teacher Education Journal*, *124*. https://doi.org/10.1016/j.tate.2023.104039

Kingkaew, C., Theeramunkong, T., Supnithi, T., Chatpreecha, P., Morita, K., Tanaka, K., & Ikeda, M. (2023). A Learning Environment to Promote Awareness of the Experiential Learning Processes with Reflective Writing Support. *Education Sciences*, *13*(1), 64. https://doi.org/10.3390/educsci13010064

Kitchenham, A. (2008). The Evolution of John Mezirow's Transformative. *Journal of Transformative Education*, *6*(2), 104–123.

Kılıç, A. (2022). The impact of reflective practices on pre-service science teachers classroom teaching practices. *Journal of Pedagogical Research*, *6*(1), 152–170. https://doi.org/10.33902/jpr.2022175781

Kramer, M. (2018). Promoting teachers' agency: reflective practice as transformative disposition. *Reflective Practice*, *19*(2), 211–224. https://doi.org/10.1080/14623943.2018.1437405

Kulgemeyer, C., Kempin, M., Weißbach, A., Borowski, A., Buschhüter, D., Enkrott, P., Reinhold, P., Riese, J., Schröder, J., Vogelsang, C., Kulgemeyer, C., Kempin, M., Weißbach, A., Borowski, A., Buschhüter, D., Enkrott, P., Reinhold, P., Riese, J., Schecker, H., & Schröder, J. (2021). Exploring the impact of pre-service science teachers ' reflection skills on the development of professional knowledge during a field experience. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2021.2006820

Kurniawan, W., Darmaji, D., Astalini, A., Kurniawan, D. A., & Hidayat, M. (2019). Multimedia physics practicum reflective material based on problem solving for science process skills. *International Journal of Evaluation and Research in Education*, *8*(4), 590–595. https://doi.org/10.11591/ijere.v8i4.20258

Lebedev, P., & Sharma, M. D. (2019). Riddles on youtube: Investigating the potential to engage viewers in reflective thinking. *Research in Learning Technology*, *27*(1063519), 1–12. https://doi.org/10.25304/rlt.v27.2280

Leopold, H., & Smith, A. (2020). Implementing Reflective Group Work Activities in a Large Chemistry Lab to Support Collaborative Learning. *Education Science*.

Leung, J. S. C. (2022). Shifting the Teaching Beliefs of Preservice Science Teachers About Socioscientific Issues in a Teacher Education Course. *International Journal of Science and Mathematics Education*, *20*(4), 659–682. https://doi.org/10.1007/s10763-021-10177-y

Lin, F., Chan, C. K. K., & Lin, F. (2018). Promoting elementary students ' epistemology of science through computer-supported knowledge-building discourse and epistemic reflection and epistemic reflection. *International Journal of Science Education*, *0693*. https://doi.org/10.1080/09500693.2018.1435923

Maksimović, J., & Osmanović, J. (2019). Perspective of cognitive thinking and reflective teaching practice. *International Journal of Cognitive Research in Science, Engineering and Education*, *7*(2), 1–10. https://doi.org/10.5937/IJCRSEE1902001M

Mamlok-Naaman, R., & Eilks, I. (2012). Different Types of Action Research To Promote Chemistry Teachers' Professional Development-a Joined Theoretical Reflection on Two Cases From Israel and Germany. *International Journal of Science and Mathematics Education*, *10*(3), 581–610. https://doi.org/10.1007/s10763-011-9306-z

Mccollough, C., Ph, D., Wolff-murphy, S., Ph, D., Blalock, G., & Ph, D. (2019). Reforming Science Teacher Education with Cultural Reflection and Practice. *International Journal of Learning, Teaching and Educational Research*, *18*(1), 31–49.

Menon, D., & Azam, S. (2021). Investigating Preservice Teachers' Science Teaching Self-Efficacy: an Analysis of Reflective Practices. *International Journal of Science and Mathematics Education*, *19*(8), 1587–1607. https://doi.org/10.1007/s10763-020-10131-4

Muhammad, H., Zafeer, I., Li, Y., & Maqbool, S. (2023). An Approach to Progress Learning Outcomes : International Graduate Students ' Engagement in Reflective Practice and Reflective Journal Writing during Pandemic. *Sustainability*.

Naidoo, K., Naidoo, L. J., & Naidoo, K. (2021). Designing teaching and reflection experiences to develop candidates ' science teaching self-efficacy candidates ' science teaching self-efficacy ABSTRACT. *Research in Science & Technological Education*, *00*(00), 1–21. https://doi.org/10.1080/02635143.2021.1895098

Nazleen, S., Rabu, A., & Badlishah, N. S. (2020). Levels of Students ' Reflective Thinking Skills in a Collaborative Learning Environment Using Google Docs. *TechTrends*, 533–541.

Oliveira, A. W., Brown, A. O., Carroll, M. L., Austin, B., Bretzlaff, T., Oliveira, A. W., Brown, A. O., & Carroll, M. L. (2021). Developing undergraduate student oral science communication through video reflection. *International Journal of Science Education, Part B*, *0*(0), 1–12. https://doi.org/10.1080/21548455.2021.1907630

Onrubia, J., Roca, B., & Minguela, M. (2022). Assisting teacher collaborative discourse in professional development: An analysis of a facilitator's discourse strategies. *Teaching and Teacher Education*, *113*. https://doi.org/10.1016/j.tate.2022.103667

Orakcı, Ş. (2021). Teachers' Reflection and Level of Reflective Thinking on the Different Dimensions of their teaching practice. *International Journal of Modern Education Studies*, *5*(1), 117. https://doi.org/10.51383/ijonmes.2021.88

Orcid, F. G. K., Berk, A., Orcid, U., Orcid, K. Z., Orcid, R. Y., & Received, T. (2023). Metacognitive Awareness , Reflective Thinking , Problem Solving , And Community Of Inquiry As Predictors Of Academic Self-Efficacy In Blended Learning : A Correlational Study. *Turkish Online Journal of Distance Education-TOJDE*, *January*, 20–36.

Öztürk, M. (2020). The Relationship between Self-Regulation and Proportional Reasoning: The Mediating Role of Reflective Thinking towards Problem Solving. *Egitim ve Bilim*, *45*(204), 143–155. https://doi.org/10.15390/EB.2020.8480

Parmigiani, D. (2019). *Cloud-Based M-Learning in a University Context : Student-Teachers ' Perspectives on the Development of their Own Reflective Thinking*. 669–681.

Parmigiani, D., Benigno, V., & Hidi, A. (2019). Cloud-Based M-Learning in a University Context: Student-Teachers' Perspectives on the Development of their Own Reflective Thinking. *TechTrends*, *63*(6), 669–681. https://doi.org/10.1007/s11528-019-00412-3

Parmin. (2019). *The Application of STEM Education in Science Learning at Schools in Industrial Areas*. *16*(2), 278–289. https://doi.org/10.12973/tused.10281a

Postholm, M. B. (2018). Reflective thinking in educational settings: an approach to theory and research on reflection. *Educational Research*, *60*(4), 427–444. https://doi.org/10.1080/00131881.2018.1530947

Puig, M. S., Sánchez-Martí, A., Ruiz-Bueno, A., & Sánchez-Santamarí, J. (2020). The effects of learning contexts on the development of reflective thinking in university education: Design and validation of a questionnaire. *Sustainability (Switzerland)*, *12*(8), 1–18. https://doi.org/10.3390/SU12083298

Quarderer, N. A., & Mcdermott, M. A. (2020). Examining Science Teacher Reflections on Argument-Based Inquiry Through a Critical Discourse Lens. *Research in Science Education*, 2483–2504.

Rodgers, C. (2002). Defining Reflection: Another look at john Dewey and reflective thinking. Teachers College Record. In *Teachers College Record* (Vol. 104, Issue 4, pp. 842–866).

Ronen, I. K. (2020). Empathy Awareness Among Pre-service Teachers: the Case of the Incorrect Use of the Intuitive Rule "Same A–Same B." *International Journal of Science and Mathematics Education*, *18*(1), 183–201. https://doi.org/10.1007/s10763-019-09952-9

Rosmiati, R., Liliasari, L., Tjasyono, B., Ramalis, T. R., & Satriawan, M. (2020). Measuring level of reflective thinking of physics pre-service teachers using effective essay argumentation. *Reflective Practice*, *21*(4), 565–586. https://doi.org/10.1080/14623943.2020.1777957

Sarı, U., Çelik, H., Pektaş, H. M., & Yalçın, S. (2022). Effects of STEM-focused Arduino practical activities on problem-solving and entrepreneurship skills. *Australasian Journal of Educational Technology*, *38*(3), 140–154. https://doi.org/10.14742/ajet.7293

Sebatana, M. J., & Dudu, W. T. (2022). Reality or Mirage: Enhancing 21st-Century Skills Through Problem-Based Learning While Teaching Particulate Nature of Matter. *International Journal of Science and Mathematics Education*, *20*(5), 963–980. https://doi.org/10.1007/s10763-021-10206-w

Slepcevic-Zach, P., & Stock, M. (2018). ePortfolio as a tool for reflection and self-reflection. *Reflective Practice*, *19*(3), 291–307. https://doi.org/10.1080/14623943.2018.1437399

Son, J. W., & Lee, M. Y. (2021). Exploring the Relationship Between Preservice Teachers' Conceptions of Problem Solving and Their Problem-Solving Performances. *International Journal of Science and Mathematics Education*, *19*(1), 129–150. https://doi.org/10.1007/s10763-019-10045-w

Stylianides, G. J., Stylianides, A. J., & Shilling-Traina, L. N. (2013). Prospective Teachers' Challenges in Teaching Reasoning-and-Proving. *International Journal of Science and Mathematics Education*, *11*(6), 1463–1490. https://doi.org/10.1007/s10763-013-9409-9

Swanson, K. W. (2010). Constructing a learning partnership in transformative teacher development. *Reflective Practice*, *11*(2), 259–269. https://doi.org/10.1080/14623941003672428

Tran, K., Barrera, A. M., Coble, K., Arreguin, M., Harris, M., Macha-lopez, A., Perez, M., & Eroy-reveles, A. (2022). Cultivating cultural capitals in introductory algebra-based physics through reflective journaling. *Physical Review Physics Education Research*, *18*(2), 20139. https://doi.org/10.1103/PhysRevPhysEducRes.18.020139

Treibergs, K. A., Esparza, D., Yamazaki, J. A., Goebel, M., & Smith, M. K. (2022). *How do introductory field biology students feel ? Journal reflections provide insight into student affect*. *September*, 1–20. https://doi.org/10.1002/ece3.9454

van Velzen, J. H. (2015). Are students intentionally using self-reflection to improve how they learn? Conceptualising self-induced self-reflective thinking. *Reflective Practice*, *16*(4), 522–533. https://doi.org/10.1080/14623943.2015.1064378

Vogelsang, C., Kulgemeyer, C., & Riese, J. (2022). Learning to Plan by Learning to Reflect?—Exploring Relations between Professional Knowledge, Reflection Skills, and Planning Skills of Preservice Physics Teachers in a One-Semester Field Experience. *Education Sciences*, *12*(7). https://doi.org/10.3390/educsci12070479

Walan, S. (2020). Embracing Digital Technology in Science Classrooms—Secondary School Teachers' Enacted Teaching and Reflections on Practice. *Journal of Science Education and Technology*, *29*(3), 431–441. https://doi.org/10.1007/s10956-020-09828-6

Wang, J. R., & Lin, S. W. (2008). Examining reflective thinking: A study of changes in methods students' conceptions and understandings of inquiry teaching. *International Journal of Science and Mathematics Education*, *6*(3), 459–479. https://doi.org/10.1007/s10763-007-9085-8

Williams, A. T. (2020). Growing student teachers' reflective practice: explorations of an approach to video-stimulated reflection. *Reflective Practice*, *21*(5), 699–711. https://doi.org/10.1080/14623943.2020.1798917

Wilson, J. P. (2008). Reflecting-on-the-future: a chronological consideration of reflective practice. *Reflective Practice*, *9*(2), 177–184. https://doi.org/10.1080/14623940802005525

Woolway, J., Msimanga, A., & Lelliott, A. (2019). Continuous Collaborative Reflection Sessions in a Professional Learning Community: The Development of Grade 8 Natural Sciences Teachers' Reflective Practice. *African Journal of Research in Mathematics, Science and Technology Education*, *23*(1), 1–13. https://doi.org/10.1080/18117295.2018.1555985

Yang, Y., Zhu, G., Sun, D., & Chan, C. K. K. (2022). Collaborative analytics-supported reflective Assessment for Scaffolding Pre-service Teachers ' collaborative Inquiry and. *Intern. J. Comput.-Support. Collab. Learn*, 249–292.

Yu, K., Fan, S., & Lin, K. (2014). *Enhancing students ' problem-solving skills through context-based learning*. *April 2013*.

Zach, S., & Ophir, M. (2020). Using simulation to develop divergent and reflective thinking in teacher education. *Sustainability (Switzerland)*, *12*(7). https://doi.org/10.3390/su12072879