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# A SYSTEMATIC LITERATURE REVIEW OF STUDIES ON METACOGNITION IN SCIENCE, PHYSICS, CHEMISTRY AND BIOLOGY EDUCATION

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**Abstract**

Metacognition, the ability to be aware of, monitor, and, when necessary, regulate one's own thinking processes, is crucial in education as it enables students to manage their learning processes more consciously. In this study, articles related to metacognition in the Web of Science database between 2009 and 2025 were identified for the purpose of a systematic literature review of metacognition-themed research in science fields. These articles were screened according to inclusion and exclusion criteria, and the remaining 32 articles were examined. Publications in the field of cognitive science in the natural sciences have been found to be most prevalent in chemistry and science education, and least prevalent in physics and biology education. The participating groups have been found to consist predominantly of university-level teacher candidates and secondary school students. Sample sizes range from 30 to 950. In studies featuring quasi-experimental, experimental, and causal comparative designs, the metacognitive awareness inventory (MAI), problem-solving tests, reflective thinking forms, observations, and questionnaires are frequently used data collection tools. According to the findings of the study, incorporating metacognitive strategies into teaching processes has been found to enhance students' academic achievement, motivation, problem-solving, and self-regulation skills. Structured metacognitive activities have been found to be effective in reducing misconceptions and improving students' attitudes towards learning. It has been observed that supporting the sub-dimensions of metacognition, particularly planning, monitoring, evaluation and decision-making, in the educational process contributes to the development of scientific thinking and learning responsibility in students. Furthermore, it is recommended that metacognition-based teaching approaches in science subjects such as physics, chemistry and biology be systematically structured and that practical examples targeting these skills be increased in teacher training.

**Keywords:** Science education fields, metacognitive awareness, systematic literature review, metacognition

## INTRODUCTION

Cognition is the process by which knowledge is acquired in an individual's brain. It is a mental process that encompasses the skills necessary for encoding, storing and retrieving information (Anderson, 1990; Dökme & Koyunlu Ünlü, 2021; Hutner & Markman, 2016; Schraw et al., 2006). The concept of metacognition has been systematically addressed in cognitive psychology alongside Flavell's (1976; 1979) pioneering studies and has become a fundamental building block in explaining the nature of learning. Flavell (1979) defined metacognition as an individual's awareness, monitoring, and regulation of their own cognitive processes, emphasizing that this process plays a decisive role in learning.

Brown (1978) also defined metacognition as the learner consciously managing their cognitive strategies and controlling these processes according to their goals. Following these two foundational approaches, metacognition has become a broad conceptual framework encompassing numerous interrelated sub-dimensions in the literature, such as metacognitive awareness, metacognitive knowledge, metacognitive experience, cognitive monitoring, self-regulation, and comprehension monitoring (Lai, 2011; Veenman, Van Hout-Wolters & Afflerbach, 2006). In the constructivist approach to learning, how the process of structuring knowledge progresses is as important as the student's structuring of knowledge in determining the quality of learning. For this reason, metacognition emerges as an important concept in contemporary cognitive theories as a mechanism that directs and regulates the learning process (Brown, 1987; Flavell, 1979). Metacognition, although it gained a conceptual foundation in the 1970s through the work of Flavell and Brown, has been defined in science education literature over the past twenty years as one of the most critical cognitive processes that enhance the quality of learning (Flavell, 1979; Schraw & Moshman, 1995). Recent studies indicate that metacognitive knowledge and metacognitive regulation strategies have a decisive impact on students' problem solving, conceptual understanding, scientific explanation development, and learning motivation (Dökme & Ünlü, 2019; González & Paoloni, 2020; Zion & Cohen, 2021).

The dimensions and components of metacognition have been identified by numerous researchers, but in the most general sense, metacognition is classified into the dimensions of metacognitive knowledge and metacognitive organization (Akın & Abacı, 2011; Brown, 1978; Değirmenci, 2025; Schraw & Moshman, 1995). Metacognitive knowledge refers to an individual's awareness of the cognitive skills they use while performing a task, their ability to monitor their progress in this process, and their knowledge and beliefs about available resources. This type of knowledge encompasses all mental stages that an individual plans and structures in relation to themselves and their environment, in pursuit of a specific cognitive goal. Individuals with metacognitive knowledge know when, where, and how to engage their metacognitive processes (Lucangeli & Cornoldi, 1997; Schraw & Moshman, 1995). The second dimension, which refers to metacognitive regulation, encompasses the decisions an individual makes while performing a given task and all the strategic activities carried out during this process. Metacognitive regulation consists of metacognitive skills such as predicting, planning, monitoring and evaluating (Brown, 1978; Jacobs & Paris, 1987; Lucangeli & Cornoldi, 1997; Schraw & Moshman, 1995; Veenman vd., 2020; Zepeda vd., 2020). Flavell (1979) addressed metacognition and cognitive control under four fundamental dimensions. These dimensions are defined as metacognitive knowledge, metacognitive experiences, goals (tasks) and processes (strategies).

Metacognitive knowledge refers to an individual's awareness of their own cognitive characteristics, the requirements of tasks, and the strategies that can be used to accomplish these tasks. This component encompasses individuals' understanding of what they know, how they learn, and which strategies are most effective in specific contexts (Flavell, 1979; Schraw & Moshman, 1995).

Metacognitive experiences encompass the momentary awareness, emotions, and judgements that arise during cognitive activities. These experiences reflect individuals' subjective evaluations of their ongoing learning processes and play a critical role in regulating cognition by providing instantaneous internal feedback (Efklides, 2006; Flavell, 1979).

Goals or tasks express the outcomes that individuals aim to achieve during cognitive engagement and the expectations associated with these outcomes. The nature of these goals directly influences individuals' levels of cognitive effort and strategy selection (Flavell, 1979; Pintrich, 2002).

Processes and strategies encompass the cognitive and metacognitive processes individuals use to achieve their goals. These processes include planning, monitoring, evaluating, and revising the approach when necessary; all of these are central to metacognitive regulation (Flavell, 1979; Brown, 1987; Schraw et al., 2006). Taken together, these four components form an integrated structure that enables learners to manage their learning processes in a deliberate, controlled and goal-oriented manner.

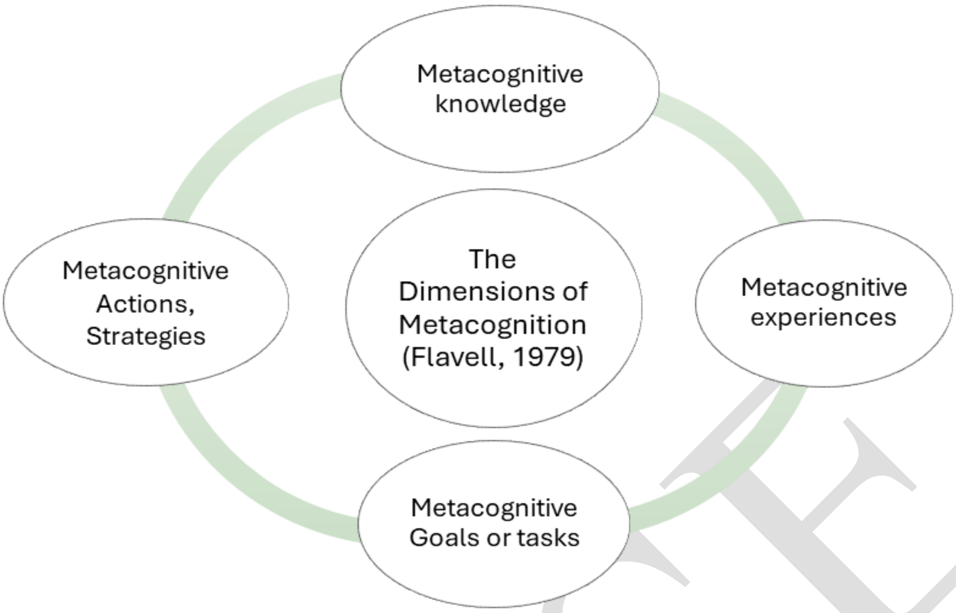


**Figure 1.** Flavell (1979), Schematic of the dimensions of metacognition.

Following Flavell, one of the researchers who made significant contributions to the field of metacognition was Brown. Brown (1987) addressed metacognition within the framework of two fundamental components: cognitive knowledge and cognitive regulation. Cognitive knowledge encompasses an individual's conscious reflection on their own cognitive abilities and mental activities, while cognitive regulation refers to an individual's self-regulatory behaviors in learning or problem-solving processes. According to Brown, although these two components are considered separately conceptually, they interact closely with each other in the learning process and play a mutually supportive role (Brown et al., 1983; Brown, 1987).

Brown's metacognitive model is presented in the diagram in Figure 2.

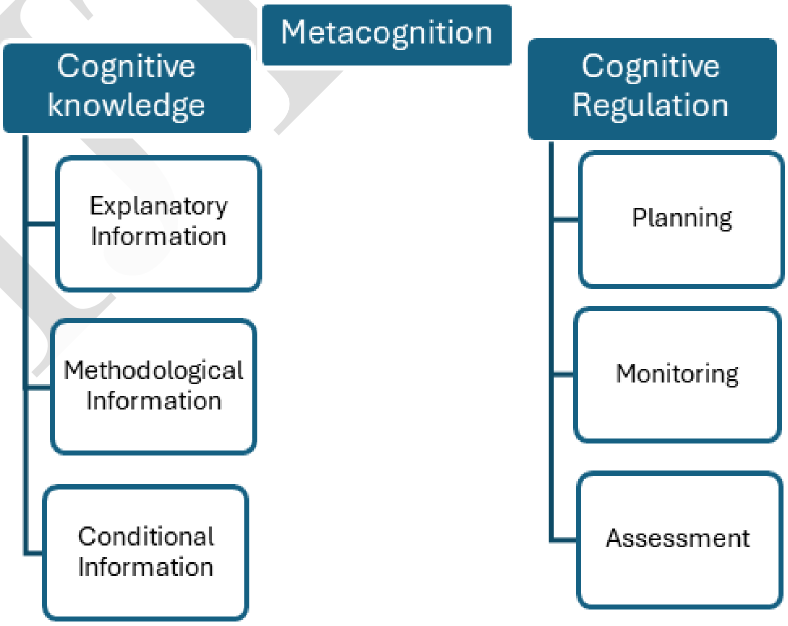


**Figure 2.** Brown's metacognitive model

Cognitive knowledge refers to an individual's awareness of their own cognitive processes, their recognition of these processes, and their ability to express the knowledge they possess about them. In other words, it is the ability to know what one knows and to consciously evaluate one's own knowledge; in this sense, it is also defined as "awareness of knowing" (Brown, 1987).

Declarative knowledge encompasses information about factors that influence an individual's learning process, their own learning characteristics, and their cognitive abilities. Procedural knowledge refers to an individual's ability to select an appropriate strategy for a specific cognitive task and to know how to implement the selected strategy (Schraw et al., 1995). In other words, it refers to the knowledge of which strategies to use and how to implement them in order to complete a task effectively and successfully (Aktürk et al., 2011). On the other hand, situational knowledge involves the individual being aware of the conditions, timing and purpose for which declarative and procedural knowledge should be used. This type of knowledge enables the individual to organise their cognitive activities in a manner appropriate to the situation (Schraw et al., 1995). Cognitive regulation refers to the process of controlling and directing an individual's cognitive processes. This process occurs through the individual monitoring their own thoughts, adjusting and evaluating them when necessary, and adapting the learning process accordingly. Cognitive regulation encompasses various cognitive activities such as goal setting, resource planning, attention management, problem-solving strategies, and performance evaluation. In this context, cognitive regulation offers a self-regulating structure that helps individuals consciously control and sustain their learning processes (Brown, 1987). Planning, monitoring and evaluation are considered fundamental metacognitive strategies in this process (Nazarieh, 2016).

**Planning** is the process whereby an individual determines appropriate strategies for solving a problem they encounter and makes the necessary arrangements for the learning process in advance. This process represents the preparatory stage that determines the direction and scope of learning (Nazarieh, 2016).

**Monitoring** is the process of evaluating the effectiveness of the learning or problem-solving process undertaken by the individual, questioning whether the strategies used are effective, and identifying potential errors in the process (Schraw et al., 1995).

**Evaluation,** on the other hand, refers to the process of reviewing an individual's performance at the end of the problem-solving process or throughout the process, thereby reorganizing the learning process (Brown, 1987).

### The Purpose of Research

The aim of this research is to systematically review Web of Science (WoS) indexed studies addressing the concept of metacognition in science, physics, chemistry and biology education, thereby revealing research trends, methodological characteristics and prominent findings in the field. In this context, studies published between 2009 and 2025 were analyzed in terms of publication year, journal type and index, institutional distribution of authors, keywords used, research methods and designs, sample characteristics, data collection tools, and data analysis techniques. Furthermore, by evaluating the general trends and recommendations in the results obtained from the studies reviewed, the aim is to identify existing research gaps in the field of metacognition in the context of science education and to present conclusions that will guide future studies.

### Problem

The concept of metacognition in science education has attracted increasing interest in recent years and has been the subject of numerous studies in the context of different age groups, teaching approaches and learning environments. Metacognition has gained an important place in science education literature because it involves the processes of planning, monitoring and evaluating learning. However, studies providing a comprehensive and systematic overview of which sample groups metacognitive research focuses on, which research designs are preferred, which data collection tools are used, and in which indices and countries the studies are published are limited. The lack of systematic examination of methodological trends and research focuses on literature makes it difficult to identify the direction of development and existing gaps in metacognitive research. This situation necessitates the identification of current trends in the field of metacognition in science education and guidance for future research. In this context, this study aims to examine the publication characteristics, methodological preferences, participant groups, and data collection tools of metacognition research in science education.

**Sub-problems**

This study sought to answer two important questions.

1) What are the defining characteristics of articles dealing with metacognition?

- What is the distribution of authors' affiliated institutions (Turkish/international)?
- What is the distribution of articles by journal?
- What is the distribution by year?
- What are the most frequently used keywords in articles?

2) What are the methodological characteristics of articles dealing with metacognition?

- How are the research methods and designs distributed?
- What data collection tools were used?
- What data analysis techniques were used?

3) How are the results and recommendations presented in the articles distributed?

## METHOD

### Research Model

This research is a study based on a systematic literature review model. The study systematically examined studies published in the Web of Science (WoS) database between 2009 and 2025 that addressed the topic of metacognition in science, physics, chemistry, and biology education according to specific criteria. The literature review and study selection process were structured in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) principles.

In this model, studies using the specified keywords were filtered according to inclusion and exclusion criteria, and suitable articles formed the data source for the research. The studies examined were analyzed in terms of their descriptive characteristics, methodological structures, and results/recommendations to reveal general trends in the field. In this context, the research is a descriptive systematic review study that aims to define and synthesize the existing literature.

### Data Collection and Analysis

In this study, a total of 32 articles published in the Web of Science database between 2009 and 2025 were systematically reviewed. During data collection, 62 articles were accessed. The process followed in the study was reported according to the PRISMA flow chart.

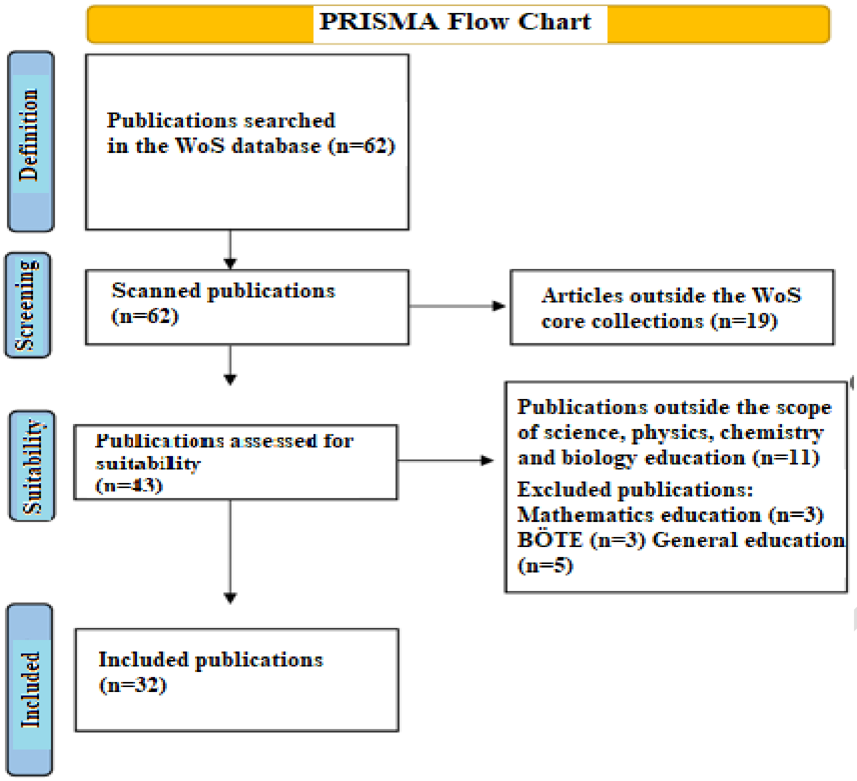


**Figure 3.** PRISMA flow diagram.

Keywords used in the systematic literature review conducted in the Web of Science (WoS) database: Metacognition, Science education, Physics education, Chemistry education, Biology education, “Metacognition” AND “Science Education”.

### Data Analysis

In the analysis of the articles included in the study, the "Postgraduate Thesis Review Form" developed by Acar (2023) was used. According to this form, the studies were examined in three main dimensions: descriptive characteristics, methodological characteristics, and results-recommendations. In the descriptive analysis, the publication year of the articles, the journals in which they were published, the types of WoS indices, the institutional distribution of authors, and the keywords used were evaluated. In the methodological analysis, research methods and designs, sample groups and sizes, data collection tools, and data analysis techniques were considered. Finally, the findings, conclusions, and recommendations presented in the articles were examined in terms of content, and common trends and noteworthy themes were identified. The data obtained were analyzed using a descriptive analysis approach; the findings were presented visually through tables and graphs. During this process, "M" codes were assigned to each article to ensure a systematic review.

## RESULTS

This section presents the findings of studies obtained from the Web of Science (WoS) database and included in the scope of the research. The descriptive and methodological characteristics of the studies examined, along with their conclusions and recommendations, are summarized with the aid of tables and graphs.

Descriptive Characteristics of the Studies

The question "What are the defining characteristics of articles dealing with metacognition?" was addressed. Four sub-questions were answered in relation to this. Sub-questions:

- What is the distribution of the authors' affiliations (Turkish/international)?
- What is the distribution of the articles according to the journals in which they were published?
- What is the distribution by year?
- What are the most frequently used keywords in articles?

This sub-heading presents findings regarding the descriptive characteristics of the studies examined within the scope of this research. The publication years of the studies, the journals in which they were published, and the metacognitive focus areas they address are summarized in Table 1.

**Table 1.** The defining characteristics of the studies

| Code | Author(s) | Journal | Year | Key Focus / Topic |
|---|---|---|---|---|
| M1 | Chang, et al. | Journal of Biological Education | 2018 | Inquiry-based learning, metacognition, central dogma |
| M2 | Eticha, et al. | Journal of Science Education and Technology | 2024 | Biology, contextual analysis, metacognitive support, problem solving |
| M3 | Zion & Cohen | Sustainability | 2021 | Metacognitive awareness, healthy eating, biology |
| M4 | Arjaya et al. | International Journal of Instruction | 2023 | Digital literacy, metacognition, biology teacher candidates |
| M5 | Zulfiani et al. | Jurnal Pendidikan dan Pembelajaran IPA | 2020 | Metacognitive attitudes, biology teacher candidates |
| M6 | Dökme & Koyunlu-Ünlü | Research in Science Education | 2019 | Metacognition, problem solving, quantum physics |
| M7 | Dori et al. | International Journal of Science Education | 2018 | Context-based learning, metacognitive cues |
| M8 | Parlan et al. | International Journal of Instruction | 2018 | Metacognitive strategy, scientific explanation |
| M9 | Heidbrink & Weinrich | Chemistry Education Research and Practice | 2021 | Metacognition, PCK, chemistry education |
| M10 | Mathabathe & Potgieter | International Journal of Science Education | 2017 | Collaborative learning, metacognitive regulation |
| M11 | Chia yu Wang | Research in Science Education | 2014 | Metacognitive assessment, performance level |
| M12 | González & Paoloni | Chemistry Education Research and Practice | 2020 | Self-regulation, expectation-value, metacognition |
| M13 | Sawuwu & Partana | International Journal of Instruction | 2018 | Chemical text reading, metacognition |
| M14 | Vogelzang et al. | Instructional Science | 2021 | Scrum methodology, context-based learning |
| M15 | Fuchs et al. | Journal of Chemical Education | 2024 | Programming education, metacognition |
| M16 | Eticha, et.al. | Journal of Science Education and Technology | 2024 | Metacognitive support, biology teaching |
| M17 | Dökmecioğlu et al. | Educational Studies | 2020 | Critical thinking, metacognitive self-regulation |
| M18 | Sagun & Prudente | Educational Action Research | 2021 | PDSA model, metacognition-oriented environment |
| M19 | Zheng et al. | The Internet and Higher Education | 2019 | Group metacognition, collaborative learning |
| M20 | Yerdelen-Damar & Eryılmaz | Research in Science Education | 2019 | Conceptual understanding, metacognition, physics |
| M21 | Zohar & Barzilai | Studies in Science Education | 2013 | Metacognition, teacher knowledge |
| M22 | Chen et al. | Educational Sciences | 2024 | Metacognition, science education |
| M23 | Wang et al. | International Journal of Science Education | 2025 | Problem solving, metacognitive awareness |
| M24 | Kuvac & Koç | Research in Science | 2018 | Metacognitive awareness, problem-based learning, |

| | | | | |
|---|---|---|---|---|
| | | Education | | teacher candidates, science education, teacher training |
| M25 | Yenice | Educational Sciences: Theory & Practice | 2015 | Epistemological beliefs, NOS, metacognition |
| M26 | Tuononen et al. | Higher Education | 2022 | Metacognitive awareness, learning profiles |
| M27 | Abd-El-Khalick & Akerson. | International Journal of Science Education | 2009 | Metacognitive strategy training, NOS |
| M28 | Eticha et al. | The Journal of Educational Research | 2024 | Metacognitive framework, biology |
| M29 | Angell et al. | CBE—Life Sciences Education | 2024 | Metacognitive assessment, exam success |
| M30 | Dinçol-Özgür | European Journal of Psychology of Education | 2024 | Inquiry-based learning · Metacognitive thinking skills · Perception of problem-solving skills · Scientific writing intuitive method · Teaching experience |
| M31 | Blackford et al. | Chemistry Education Research and Practice | 2023 | Organic chemistry, metacognitive regulation |
| M32 | Espinosa et al. | Journal of Chemical Education | 2024 | Conceptual analysis, concept inventory |

This table presents studies published in the Web of Science (WoS) database between 2009 and 2025 that address the topic of metacognition in the fields of science, physics, chemistry, and biology education. The studies were coded M1–M32 during the analysis process.
Within the scope of the research, the diagram in Figure 4 answers the question, "What is the distribution of the institutions to which the authors are affiliated (Turkish/international)?"

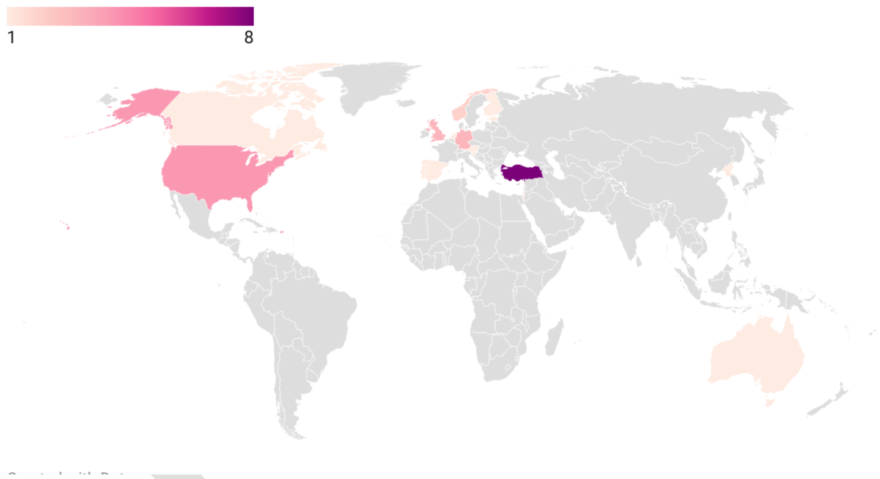


**Figure 4.** Distribution of authors' affiliated institutions by country.

Figure 4 shows that research on metacognition is concentrated in certain countries. It is particularly noteworthy that Turkey has the highest number of publications. Turkey is followed by the United States and some European countries. When the map is considered as a whole, it can be seen that the studies are largely concentrated in North America and Europe, with other continents being represented to a more limited extent. This distribution shows that metacognitive research is concentrated in certain academic centers but is also addressed to a certain extent in different countries.

Based on the table, the distribution of journals in which the studies were published is shown in the graph in Figure 5.

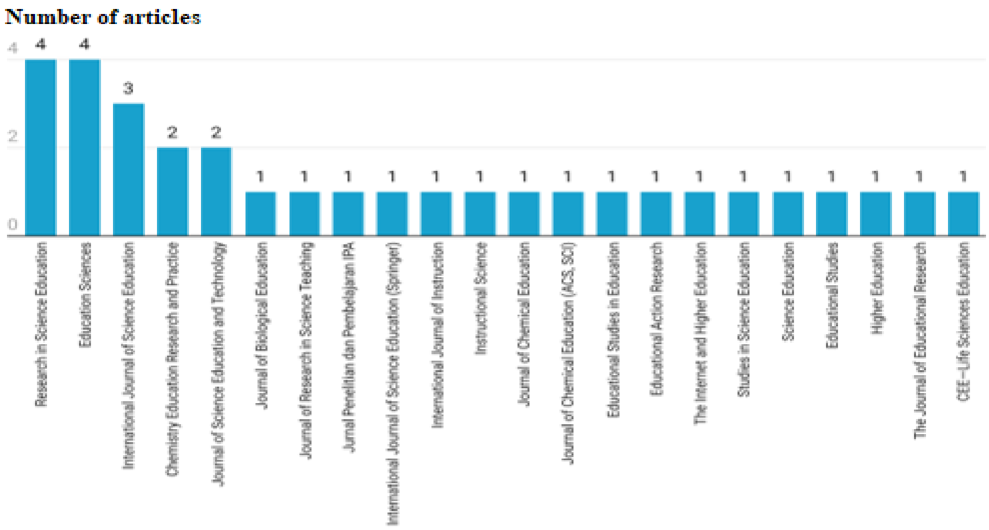


**Figure 5.** Distribution of Journals in Which Articles Were Published

The findings indicate that research is predominantly concentrated in journals that hold a central position in the field of science education, such as Research in Science Education, Education Sciences, and the International Journal of Science Education. However, a significant number of studies are also published in discipline-based journals such as Chemistry Education Research and Practice, the Journal of Chemical Education, and the Journal of Science Education and Technology. Furthermore, the presence of individual publications in numerous journals demonstrates that metacognitive research is not limited to specific core journals; rather, it is disseminated through a broad network of publications across different educational contexts and disciplines. It shows the distribution of studies related to metacognition examined within the scope of the research according to Web of Science (WoS) index types. The WoS indexes included in the studies are presented under three categories: SSCI, ESCI, and SCI. These categories are shown in Figure 6.

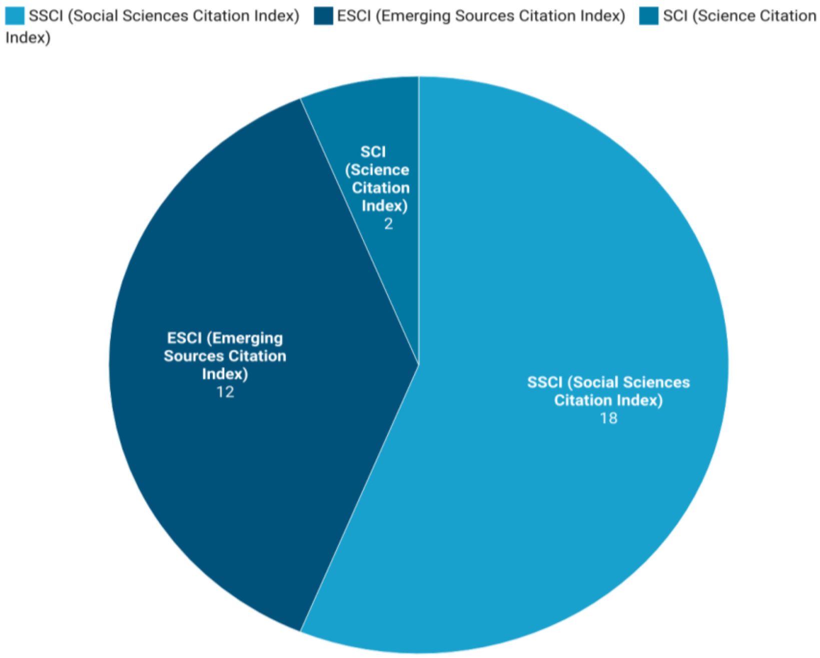


**Figure 6.** Distribution according to the Web of Science Index

The review revealed that a significant proportion of the studies included in the research were indexed in the SSCI (Social Sciences Citation Index). This finding indicates that metacognition is predominantly addressed in the social sciences and particularly in science education. The fact that a significant portion of the studies were indexed in the ESCI (Emerging Sources Citation Index) reveals that metacognition research is also being addressed with increasing interest in new journals. Conversely, the limited number of studies indexed in the SCI (Science Citation Index) indicates that the topic of metacognition is primarily addressed in the context of education and social science-based research.

The frequency distribution of studies on metacognition examined within the scope of the research is shown according to keyword groups. Keywords used in the studies have been classified under specific groups, taking into account their conceptual similarities. These classifications are shown in Figure 7.

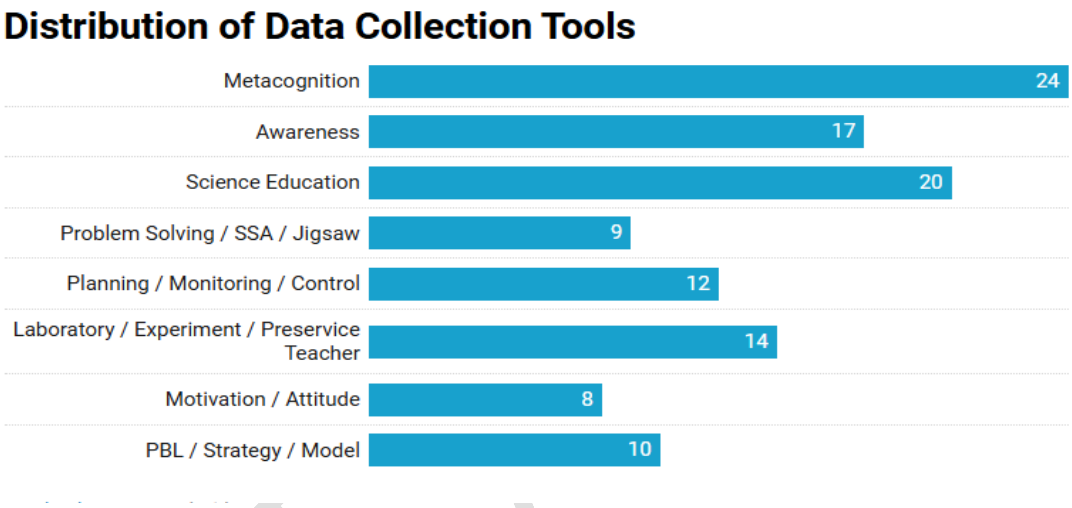


**Figure 7.** Frequency graph of keyword groups.

Figure 7 Shows the distribution of studies related to metacognition examined within the scope of the research according to participant groups. Among the keyword groups, expressions focused on "metacognition" and "science education" have the highest frequency. This finding indicates that the studies examined are directly structured around the concept of metacognition and are predominantly addressed in the context of science education. The high frequency of the keyword group "Awareness" indicates that the cognitive awareness dimension is an important focus in metacognitive research. In contrast, keywords involving metacognitive regulatory processes such as problem solving and planning/monitoring/control are represented at a moderate level. Furthermore, the low frequency of keyword groups focusing on application and instructional design, such as laboratory/experiment, teacher candidate, and PBL/strategy/model, indicates that research on application and instructional models in metacognitive studies is limited. Similarly, the relatively low frequency of motivation/attitude-focused keywords reveals that the relationship between metacognition and emotional variables is less addressed in literature.

**Methodological Characteristics of Studies**

A table has been created addressing the research question: "What are the methodological characteristics of articles dealing with metacognition?"

The table seeks answers to the following questions:

- Who comprises the sample groups?
- How are they distributed according to research methods and designs?
- What data collection tools were used?

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**Table 2.** Methodological characteristics of studies

| Code | Participant Group | Research Method / Design | Data Collection Tools |
|---|---|---|---|
| M1 | Undergraduate students (chemistry/physics) | Quasi-experimental | Problem-solving inventory, Metacognitive awareness inventory |
| M2 | Pre-school children and their teachers | Mixed method | Observation, questionnaire, reflection journal |
| M3 | Science teacher candidates | Experimental (controlled) | Metacognitive Awareness Inventory |
| M4 | Undergraduate students (multidisciplinary) | Quantitative (descriptive) | HowULearn survey (approach + metacognitive items) |
| M5 | Secondary school pupils (5 and 9 grade) | Causal comparative | Metacognitive Awareness Scale, TIMSS-like test |
| M6 | Science teacher candidates | Causal comparative | Rubric, survey, observation |
| M7 | University students | Quasi-experimental | MAI, pre-test post-test |
| M8 | Science teacher candidates | Model design research | Expert opinion (IOC) |
| M9 | Science teacher candidates | Experimental (comparative) | VNOS-C, MAI |
| M10 | Science teacher candidates | Experimental | SPST (skill test), reflection forms |
| M11 | Secondary school pupils (7th grade) | Experimental (jigsaw) | Academic achievement test, MAI, motivation scale |
| M12 | High school students | Experimental | Motivation and achievement scales |
| M13 | Undergraduate biology students | Experimental | Grade prediction, MAI, exam success |
| M14 | High school chemistry students | Case study | Reflection routine, One Minute Paper |
| M15 | Chemistry undergraduates | Mixed method (program development) | Student self-assessments, test predictions |
| M16 | Organic chemistry students | Qualitative (interview + observation) | Think-aloud, strategy report |
| M17 | High school chemistry students (Nigeria) | Correlational | MAI, academic control focus scale |
| M18 | Science teacher candidates | Measurement using a three-stage test | Three tail concept test + confidence judgement |
| M19 | Chemistry undergraduates | Case study | Program interview, observation, survey |
| M20 | Prospective chemistry teachers | Quasi-experimental | Metacognition + problem-solving scales |
| M21 | Science teacher candidates | Mixed method | Metacognition development application post-scale |
| M22 | Science teacher candidates | Experimental | Post-laboratory questionnaire + interview |
| M23 | Undergraduate biology students | Experimental (comparative) | Concept knowledge + metacognitive exam questions |
| M24 | High school students | Qualitative case study | Observation, report, student reflection |
| M25 | Chemistry undergraduates | Mixed method | Feedback, prediction, self-assessment, DK analysis |
| M26 | Organic chemistry students | Qualitative interview | Thinking of strategies and solution analysis |
| M27 | Prospective chemistry teachers | Three tail tests | Conceptual knowledge + confidence judgement |
| M28 | Undergraduate biology students | Experimental | Metacognitive preparatory assignments |
| M29 | High school students | Case study | Reflective routines, post-intervention interview |
| M30 | Prospective chemistry teachers | Mixed method | Survey, interview, teaching activities |
| M31 | Chemistry undergraduates | Program development | Task lists, confidence estimation, test estimation |

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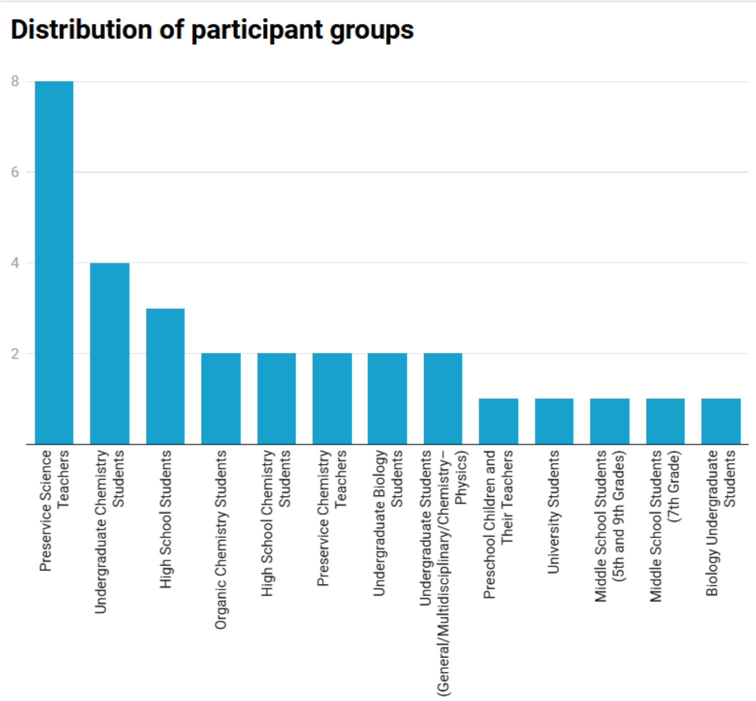


**Figure 8.** Distribution of relevant studies according to participant groups.

Figure 8 shows that most studies have been conducted on science teacher candidates. This group is followed by undergraduate chemistry students and secondary school students. The findings indicate that metacognitive research has focused predominantly on teacher candidates and students at the higher education level.

Discipline-based groups such as organic chemistry students, secondary school chemistry students and undergraduate biology students are moderately represented. In contrast, groups such as pre-school children, secondary school students and general university students are represented in a more limited number of studies.

In general, it is observed that metacognitive research sample preferences tend towards groups of students with teacher training and subject expertise, while they are addressed to a more limited extent in younger age groups and at different educational levels.

Figure 8 shows the distribution of studies related to metacognition examined in this research according to their research model/design.

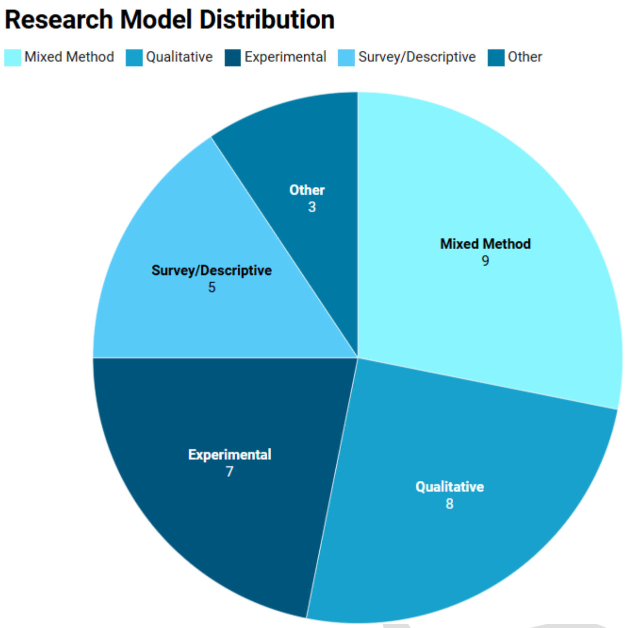


**Figure 9.** Distribution of research models

Figure 9 shows that most studies employed a mixed-methods approach. This was followed by qualitative research and experimental studies. This finding indicates that both process-oriented in-depth data collection and intervention-based experimental designs play an important role in metacognitive research. Descriptive studies are more limited in number, and studies in the "other" category are relatively underrepresented. Overall, it is evident that no single methodological approach dominates the field of metacognition; rather, there is a balanced methodological distribution involving the combined use of quantitative, qualitative, and mixed designs.

Figure 10 shows the distribution of data collection tools used in metacognitive research in science education.

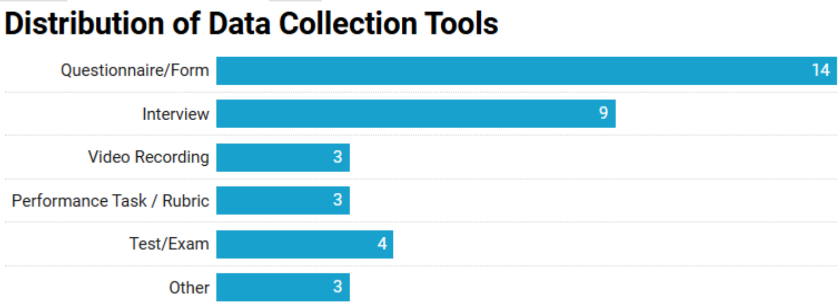


**Figure 10.** Distribution of data collection tools

Figure 10 shows that the most frequently used data collection tool in metacognition research is the questionnaire/form. Questionnaires are followed by interviews and tests/exams, respectively. This finding indicates that self-report-based measurement tools are predominantly preferred in metacognition studies. It is noteworthy that video recordings, performance tasks/assessment scales and tools in the "other" category are used less frequently. This indicates that process-oriented and performance-based measurements are relatively less common in literature. In general, it is understood that quantitative and self-report-based data collection tools are predominant in metacognitive research; conversely, observational and performance-based data collection methods are used to a more limited extent. Within the scope of this research, data is presented in Table 3 to answer the third sub-question: "How are the results and recommendations presented in the articles distributed?"

**Table 3.** Results and recommendations of the studies.

| Results | Articles |
|---|---|
| Increased Metacognitive Awareness and Skills | M12, M14, M16, M18, M22, M25, M31 |
| Metacognition Positively Affects Success, Problem Solving and Scientific Process Skills | M12, M21, M24, M26, M30 |
| Metacognition Has a Greater Effect on Students with Low Achievement Levels | M24, M28, M31 |
| Differences in the Use of Metacognitive Strategies | M15, M16, M17, M28 |
| Meaningful Relationships Exist Between Metacognition and Epistemological Beliefs and the Nature of Science | M20, M29 |
| Reflection, Discussion and Structured Feedback are Effective for the Development of Metacognition | M23, M25, M27, M31 |
| Metacognition Can Be Taught and Should Be Included in Teaching Programmes | The common conclusion drawn from all the articles |

Table 3 reveals the following findings. The majority of the studies aim to increase participants' (students or teacher candidates) metacognitive awareness levels and develop their metacognitive skills. (For example, M12, M14, M16, M18, M20, M22, M24, M25). Numerous studies have investigated the effects of teaching approaches such as problem-based learning (PBL), jigsaw, structured laboratory, model-based teaching, and reflective thinking on metacognition. (For example, M12, M14, M18, M21, M22, M23, M25). Some studies examine how metacognition relates to variables such as academic achievement, scientific process skills, problem solving, motivation and attitude. (For example, M16, M20, M21, M24, M26, M30). Some studies aim to reveal the relationships between metacognition and deeper cognitive structures such as epistemological beliefs, socio-scientific argumentation, and understanding of natural sciences. (For example, M17, M20, M29). A limited number of studies aim to develop models, programmes or measurement tools to enhance metacognitive skills. (For example, M19, M27). A small number of studies have conducted qualitative research aimed at gaining a deeper understanding of how and why students use metacognitive strategies. (For example, M28, M31). The common recommendation of the studies is that metacognition can be taught directly to both students and teacher candidates and should therefore be explicitly and systematically incorporated into education programmes. (For example, a common conclusion from all articles).

## DISCUSSION, CONCLUSION, and RECOMMENDATIONS

This study examines trends in metacognition research in science education in terms of publication distribution, country representation, research model, participant groups, and data collection tools. It demonstrates that metacognition studies are concentrated in specific journals and sample groups (Chia yu Wang, 2014; Dökme & Koyunlu Ünlü, 2019; Kuvac & Koç, 2018; Yerdelen-Damar & Eryılmaz, 2019). Looking at the distribution of publications, it can be seen that the studies are predominantly published in journals that hold a central position in the field of science education. This indicates that metacognition has become an established field of research with a strong theoretical foundation in science education literature. However, the concentration of publications in the SSCI index reveals that the subject is addressed within a social sciences and education-based framework (Abd-El-Khalick, F., & Akerson, V. L., 2009; Chen et al., 2024; Chia yu Wang, 2014; Dori et al.,2018; Dökme & Koyunlu Ünlü, 2019; Kuvac & Koç, 2018; Mathabathe & Potgieter, 2017; Wang et al., 2025; Yerdelen-Damar & Eryılmaz, 2019). Looking at the country distribution, it can be seen that the studies are concentrated in certain academic centres. This shows that, although metacognitive research is widespread globally, it is addressed more systematically in certain research cultures (Dökme & Koyunlu Ünlü, 2019; Dökmecioğlu et al., 2020; Kuvac & Koç, 2018; Yerdelen-Damar & Eryılmaz, 2019).

Methodologically, mixed methods and qualitative studies are prominent (Eticha et al., 2024; Fuchs et al. 2024; Kuvac & Koç, 2018; Yenice, 2015; Zohar & Barzilai, 2013), while experimental studies have an important but more limited share (Chang, et al., 2018; Chen et al., 2024; Chia yu Wang, 2014; Dori et al., 2018; Eticha et al., 2024; Heidbrink & Weinrich, 2021; Parlan et al., 2018; Wang et al., 2025; Yerdelen-Damar & Eryılmaz, 2019; Zion & Cohen, 2021). This finding indicates that metacognition has been addressed using both process-based and intervention-based research approaches. However, the predominance of questionnaire and self-report scales in data collection tools is noteworthy (Dökme & Koyunlu-Ünlü, 2019; Eticha et al., 2024; Fuchs et al., 2024; Yenice, 2015; Zheng et al., 2019). This demonstrates that these self-assessment tools are widely used in measuring metacognition (Fuchs et al., 2024; Yenice, 2015).

In terms of participant groups, the research primarily focuses on teacher candidates and undergraduate students (Abd-El-Khalick, & Akerson, 2009; Arjaya et al., 2023; Blackford et al., 2023; Chang et al., 2018; Chen et al., 2024; Dori et al., 2018; Dökme & Koyunlu-Ünlü, 2019; Dinçol-Özgür, 2024; Eticha et al., 2024; Fuchs et al., 2024; Heidbrink & Weinrich, 2021; Mathabathe & Potgieter, 2017; Parlan et al., 2018; Sagun & Prudente, 2021; Sawuwu & Partana, 2018; Tuononen et al., 2022; Wang et al., 2025; Yerdelen-Damar & Eryılmaz, 2019; Yenice, 2015; Zheng et al., 2019; Zion & Cohen, 2021;  Zohar & Barzilai, 2013). Early childhood (Eticha et al., 2024) and secondary school (Chia yu Wang, 2014; Zulfiani et al., 2020) and high school (Angell et al., 2024; Dökmecioğlu et al., 2020; González & Paoloni, 2020; Kuvac & Koç, 2018; Vogelzang et al., 2021) levels indicates a need for further research in these areas.

The vast majority of studies aim to increase participants' (students or trainee teachers) metacognitive awareness levels and develop their metacognitive skills (Chen et al., 2024; Eticha et al., 2024; González & Paoloni, 2020; Kuvac & Koç, 2018; Sagun & Prudente; 2021; Vogelzang et al., 2021; Yerdelen-Damar & Eryılmaz, 2019; Yenice, 2015). Numerous studies have investigated the effects of teaching approaches such as problem-based learning (PBL), jigsaw, structured laboratory, model-based teaching, and reflective thinking on metacognition (Chen et al., 2024; González & Paoloni, 2020; Sagun & Prudente; 2021; Vogelzang et al., 2021; Wang et al., 2025; Yenice, 2015; Zohar & Barzilai, 2013). Some studies examine how metacognition relates to variables such as academic achievement, scientific process skills, problem solving, motivation and attitude (Dinçol-Özgür, 2024; Eticha et al., 2024; Kuvac & Koç, 2018; Tuononen et al., 2022; Yerdelen-Damar & Eryılmaz, 2019; Zohar & Barzilai, 2013). Some studies aim to reveal the relationships between metacognition and deeper cognitive structures such as epistemological beliefs, socio-scientific argumentation, and understanding of natural sciences (Angell et al., 2024; Dökmecioğlu et al., 2020; Yerdelen-Damar & Eryılmaz, 2019). A limited number of studies aim to develop models, programmes or measurement tools to enhance metacognitive skills (Abd-El-Khalick, & Akerson, 2009; Zheng et al., 2019). A small number of studies have conducted qualitative research aimed at gaining a deeper understanding of how and why students use metacognitive strategies. (Blackford et al., 2023; Eticha et al., 2024).

The common recommendation of the studies is that metacognition can be taught directly to both students and teacher candidates and should therefore be explicitly and systematically incorporated into education programs. This study reveals that metacognitive research in science education has developed in line with certain methodological and sampling trends. Although the field exhibits methodological diversity, it largely relies on self-report-based approaches in terms of measurement tools. Furthermore, teacher candidates and higher education graduates dominate the selection of samples.

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