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ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/reac20

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To cite this article: Muhammad Zulfadhli Kamarudin & Mohd Syafiq Aiman Mat Noor (2024) What do we know about the selection of action research methodologies in primary science education? – A systematic literature review, Educational Action Research, 32:5, 825-847, DOI: 10.1080/09650792.2023.2261502

To link to this article: https://doi.org/10.1080/09650792.2023.2261502

EDUCATIONAL ACTION RESEARCH
2024, VOL. 32, NO. 5, 825–847
https://doi.org/10.1080/09650792.2023.2261502

What do we know about the selection of action research methodologies in primary science education? – A systematic literature review

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ABSTRACT

Since the development of the notion of the teacher-researcher, a range of published action research studies have focused on school-based pedagogy. Scholars agree that action research is an essential tool for teachers to improve their practice, but there is little known about the process underpinning teachers' choice of particular action research methodologies in primary science education. In this systematic literature review, 33 articles were reviewed to examine the methodological considerations teacher-researchers made when conducting action research within the primary school context, as well as the quality of the action plans and the impacts of the research on children's learning in science. The systematic review navigated existing primary science studies, focusing on methodological considerations in the choice of particular types of action research. With regards to the quality of action research studies, the reviewed articles had a good average score for all three types of validity. In terms of the effects of the employed action research methodologies, most studies demonstrated positive impacts on children's learning in science. Based on this review, it is recommended that future researchers be encouraged to carry out action research in their classroom settings, as most authors in the review favour this approach. Researchers should also examine the outcome, process, and democratic validity of their action research studies to generate better quality action plans. Lastly, primary school science teachers can adopt the various action research methodologies employed in this review since most studies support their positive impacts on children's learning in science.

ARTICLE HISTORY
Received 27 February 2023
Accepted 15 August 2023

KEYWORDS
Systematic literature review; action research; methodological choices; primary science; science education

Introduction

There are different paradigms, methodologies, and philosophies associated with action research. Kemmis et al. (2014) listed seven kinds of action research, including industrial action research, action science, action learning, soft systems approaches, participatory research, classroom action research and critical participatory action

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research. Feldman et al. (2018) defined action research as the processes related to methods professionals use to strengthen their practice and knowledge of their practice contexts, as well as to create information that can guide other practitioners in the same field. In the context of educational action research, the concept of the teacher-researcher, first introduced by Lawrence Stenhouse in 1975, has played a pivotal role in the growth and development of action research within the field of school-based pedagogy. This idea emphasises the importance of teachers actively participating in the research process and using their own professional experiences and knowledge to inform and guide the research (Stenhouse 1975). Educational action research encompasses a broad range of strategies and methodologies for innovating the practice of education through a cyclical strategy of implementing change and studying its impacts, with the primary aim of further enhancing the field (Eilks 2018).

The growing popularity of educational action research is evident in the sheer number of publications and resources available on the topic. A simple Google search returns over 290 million results, highlighting the significant interest in this approach to improving practice. Its popularity is largely related to the numerous curriculum reforms that have been implemented in recent years, which have emphasised the importance of teachers and practitioners engaging in ongoing reflection and improvement of their practice (see Elliott 2005). In the context of action research, transformation in education occurs through a bottom-up, democratic process guided by self-directed, knowledge-producing practitioners (McNiff 2016). This reflects the view that teachers become 'excellent knowers' of their classroom settings by engaging in a thorough and critical analysis of their own pedagogical practice (Hong and Salika 2011). Thus, teachers practise pedagogical action research when they utilise a reflective lens to examine a pedagogical issue or problem and formulate a sequence of active measures to address the issue (Norton 2019).

Mertler (2019) highlighted three of the most important features of action research in educational settings: connecting theory to practice, improving educational practice, and empowering teachers. Action research bridges the gap between theory and practice when teachers seek out educational theories related to their problems and adapt them to lessons specific to their own classroom settings (Kitchen and Stevens 2008). This view was supported by Ulvik (2014), who mentioned that a theoretical perspective on practice might enhance one's understanding of that practice, and conversely, the practice may enhance one's understanding of the abstract theory. As a result, action research can foster an interaction between theory and practice, where 'theory' refers to research-based knowledge and 'practice' refers to teachers' work experiences in the classroom (Ulvik, Riese, and Roness 2018).

In addition, action research improves teachers' educational practices. They are encouraged to analyse their pedagogical practices to develop a deeper understanding of their own teaching with the aim of improving their practice (James and Augustin 2018). Feldman et al. (2021) further highlighted that teachers who engaged in the systematic inquiry of action research into their teaching practice observed that the effort to acquire, create, and implement new ways of teaching resulted in the improvement of their practice and the generation of teacher knowledge. Meanwhile, Ado (2013) highlighted that teachers feel empowered when they are put in charge of their learning as part of the action research process and can immediately implement what they have learned in their classrooms. Teachers control the decision-making process, which leads to self-empowerment and self-liberation, resulting in profound personal change, which the practitioner must recognise and share with others through action research (Cabaroglu 2014; Feldman, Bennett, and Vernaza-Hernández 2015).

Primary science education paves the way for the ultimate goal of developing scientifically literate high school graduates (Akerson and Bartels 2023). The three components of scientific literacy are subject knowledge, the nature of science, and scientific inquiry (Roberts 2007). Existing action research work within primary science education settings highlights the role of related science topics (subject knowledge) and the methodological choices involved in the action plan conducted (nature of science and scientific inquiry). By compiling the diverse action plans developed as part of primary science education, this comprehensive review seeks to explore the various methodological choices teacher-researchers make when carrying out action research to ensure that young children develop scientific literacy.

Review of previous action research in science education

In previous years, a minimal number of studies have reviewed action research in the field of science education. Laudonia et al. (2018) conducted an analytical analysis of the literature to provide an overview of vital action research methodologies, techniques, issues, and accomplishments in science education. Their study highlighted that the goals of action research in science education are to comprehend better, develop teaching strategies, and contribute to teachers' ongoing professional development. To be specific, this review discussed the application of action research in science education, drawing on journal articles and book chapters from different levels of education, including primary, secondary and tertiary levels. Meanwhile, Manfra (2019) reviewed action research studies from four subject areas: English language arts, mathematics, science, and social studies. Manfra's review was predicated on the idea that modifying teaching practice depends on knowing how teachers learn. The review focused on understanding teachers' pedagogical content knowledge shifts, professional inquiry, and critical pedagogy through action research. However, as the review was focused on multidisciplinary subjects, it did not fully offer a thorough analysis of the practice of action research in science education.

Within the specific domain of science education, Keahey (2021) conducted a systematic review of participatory action research for sustainable development. The author highlighted three critical results: patterns of global participation and the need for an interdisciplinary toolkit for research and action, key challenges for research and practice, and ways to enhance engagement from suggested sustainable development strategies. However, the review only selected studies that utilised participatory action research for sustainable development in the biology domain. In conclusion, numerous search tactics throughout all scholarly databases, such as Scopus, Web of Science, Education Resources Information Center (ERIC), and Google Scholar, have not yielded any review-based study that solely focuses on action research in primary science education. In order to fill the gaps in the existing literature, a systematic literature review was undertaken to identify the methodological choices underpinning teacher-researchers' selection of particular types of action research in previous primary science studies, the quality of action research studies in the context of primary science education, and how the employed action research methodology impacted children's learning in science. Thus, this study seeks to provide answers to the following research questions:

(1) What methodological choices underpinned teacher-researchers' selection of particular types of action research in previous primary science studies?
(2) What is the quality of action research studies in the context of primary science education?
(3) In what ways did studies that employed an action research methodology impact children's learning in science?

Methodology

To conduct this systematic literature review, we adapted Zawacki-Richter et al. (2020) guidelines for carrying out Systematic Reviews in Educational Research. Based on this work, five steps were employed: (i) formulation of research questions, (ii) production of a set of selected criteria, (iii) formation of a search strategy, (iv) selection of studies based on a set of criteria, and (v) data synthesis. This review aimed to offer a new understanding of action research in primary science education, notably with regards to the methodological choices teacher-researchers made surrounding the type of action research employed, the quality of action research studies, and how the selected studies impacted children's learning in science. We were interested in the implementation of various action plans for action research in primary science education settings. Thus, three research questions were generated to fulfil the first step of the process.

In the second step, we produced a set of selected criteria for this review, based on PICo. PICo consists of the three fundamental aspects of population or problem (PI), interest (I) and context (Co) (Richardson et al. 1995). The selected criteria generated for this systematic review were primary school children (population), action research (interest), and science education (context). Furthermore, we utilised additional selection criteria: all selected journal articles were written in the English language only. Peer-reviewed journal publications were rated as more credible source than, for instance, textbooks or online websites. This method is essential because it ensures rigour by placing information under the scrutiny of specialists in the same field, thus uncovering intentional or accidental mistakes (Reifsnider 2022).

The third step followed the formation of a search strategy with two crucial keywords selected: action research and primary science. To ensure the review was engaging with the latest and most contemporary action plans employed in primary science education, the search confined the selection of articles to those published within the last 10 years, from 2012 to 2022. The articles were selected through four databases: Web of Science, Scopus, Educational Resources Information Centre (ERIC) and Google Scholar, in addition to all action research journals (e.g. Action Research), top-tier science education journals (e.g. International Journal of Science Education), and selected primary education journals (e.g. Elementary School). These terms were analysed in conjunction with their combinations using search methods such as field code functions, phrase searches, and Boolean operators. The process involved in searching for articles via Web of Science, Scopus and ERIC follows the search string that can be seen in Table 1. In addition, the investigation included a manual search strategy of 'handpicking' from Google Scholar databases and journals from across three different disciplines. We meticulously combed through the

Table 1. The search string.

Database	Search String
Web of Science	TS= (('action research') AND (primary OR elementary) AND (science))
Scopus	TITLE-ABS-KEY ('action research' AND primary OR elementary AND science) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012)) AND (LIMIT-TO (DOCTYPE, 'ar')) AND (LIMIT-TO (SUBJAREA, 'SOCI'))
ERIC	'action research' AND primary OR elementary AND science

webpage and the journal content and successfully conducted a non-indexed search in the database.

In the fourth step, we selected the studies based on the set of criteria following PRISMA (Page et al. 2021), as shown in Figure 1. In the identification phase, 414 articles were gathered from the databases and journals before 20 duplicate records were removed. Moving on to the screening process, the selected 394 studies were screened, and 346 of them were excluded as action research was not one of their primary concerns. The remaining 48 studies underwent the second screening process for eligibility, and 15 were excluded since primary school children were not actively involved as participants.

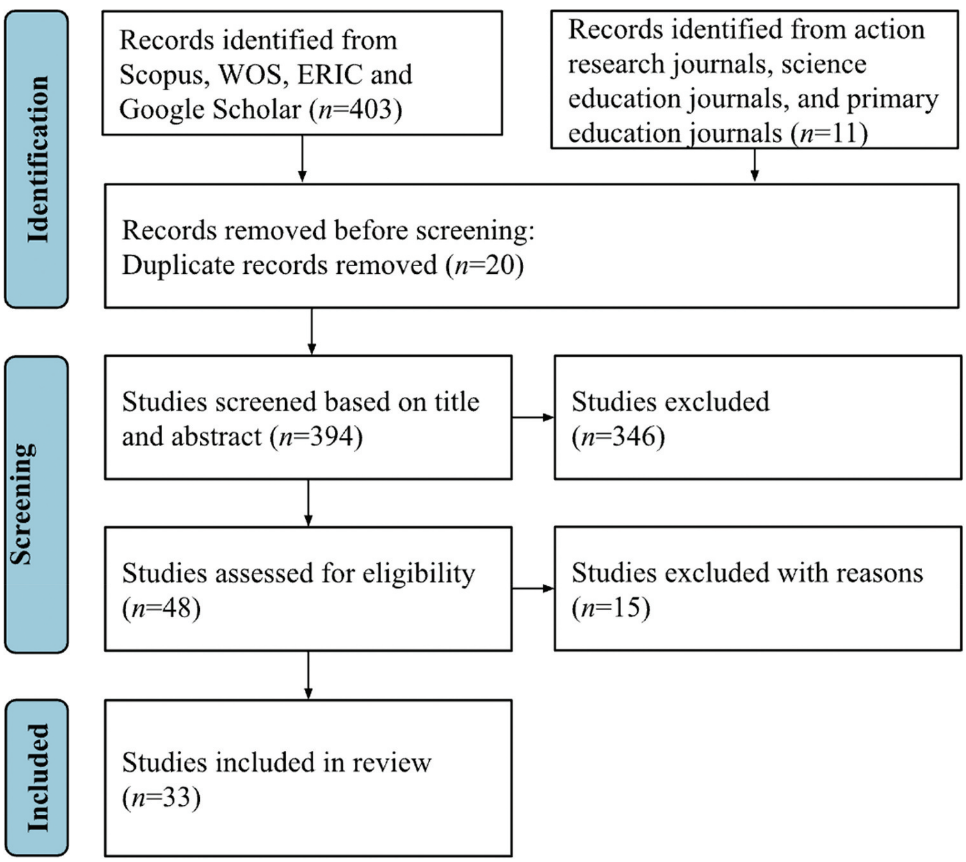

Figure 1. Selecting articles to be reviewed following PRISMA (Page et al. 2021).

In total, 33 articles were selected and included in the process of quality appraisal in step 5 (See Appendix A1). The contemporary nature of the study influenced the small number of articles chosen for this review. In a developing field of research, many inquiries remain unaddressed, and the articles available on the subject are limited and widely dispersed (Kraus, Breier, and Dasí-Rodríguez 2020).

The last step followed the data synthesis process, whereby we conducted the process of data extraction, quality assessment and thematic analysis to answer all three research questions. In the data extraction, we created a coding schema to assess the required information from the selected studies, which contained information like jurisdictions and methodological choice for the type of action research. In so doing, we answered the first research question. We then conducted the quality assessment on all the chosen action research studies, answering the second research question. Lastly, in order to respond to the third research question, we performed a reflexive thematic analysis (Braun and Clarke 2019). We identified, constructed and debated the codes and categories from the 33 studies to provide a richer interpretation of the data. Based on our collaborative theoretical assumptions, analytical skills and the interpreted data (Braun and Clarke 2021), we generated the emerging themes associated with the effects of the employed action research on children's learning in science.

Results and discussions

This systematic literature review aimed to identify the methodological choices underpinning the selection of particular types of action research in previous primary science studies, the quality of action research studies in the setting of science education at the primary level, and how the employed action research methodology impacted children's learning in science. The proposed research questions serve as the foundation for structuring the discussion of this systematic literature review.

Methodological choices underpinning the selection of particular types of action research in previous primary science studies

Table 2 shows a total of 33 articles selected for this systematic literature review. The research was conducted in 15 jurisdictions, with the majority of the studies conducted in Turkey ($n = 7$), Indonesia ($n = 6$), United States ($n = 4$), Malaysia, Sweden and the Philippines (for each: $n = 2$). The remainder of the studies were conducted in Taiwan, Brunei, Singapore, Thailand, Nepal, Jordan, South Africa, United Kingdom, Greece and Canada. The studies applied different types of action research, with most studies conducting classroom action research ($n = 17$), collaborative action research ($n = 8$), participatory action research ($n = 6$), and exploratory action research ($n = 2$). The action plan selected by the researcher covered different domains of science when the contents were presented to the children. Most studies applied topics related to Biology ($n = 19$), Physics ($n = 9$), and Chemistry ($n = 8$). The remaining four studies did not specify the domain of science in their action plan. In addition, the action plans could be categorised into different approaches, with the most popular approaches being inquiry ($n = 11$), arts-integrated ($n = 9$), collaborative projects ($n = 5$), technology-integrated ($n = 5$) and sustainable development ($n = 3$).

Table 2. Methodological choices underpinning the selection of particular types of action research in previous primary science studies.

No.	Articles	Jurisdictions	Methodological choice of action research	Action plan (Science topic)	Participants	Data collection methods	Data analysis
1	Acharya et al. (2022)	Nepal	Participatory action research	School gardening (Biology)	124 grade 6 and 7 children (12–13 years old) 20 parents 2 science teachers 20 parents 2 science teachers	• Focus group discussions • Observations	Qualitative
2	Alkiş Küçükaydin (2018)	Turkey	Classroom action research	Scientific stories and reflections (Biology)	12 grade 4 children (9 years old)	• Tests • Children's descriptions of drawings • Science diaries	Quantitative
3	Attorps and Kellner (2017)	Sweden	Collaborative action research	School-university collaboration (Biology)	9 teachers	• Audio recordings and logbooks of project meetings • Document analysis • Tests • Classroom activities and documentations • Audio-recording of teachers' experiences	Qualitative
4	Azainil et al. (2019)	Indonesia	Collaborative action research	Discovery Contextual Teaching Learning (Biology)	33 grade 6 children (11–12 years old)	• Questionnaires • Tests • Observations	Quantitative and qualitative (mixed methods)
5	Aziz et al. (2013)	Malaysia	Collaborative action research	Project-based learning (Biology)	32 grade 1 children (7 years old)	• Checklists • Photos	Qualitative
6	Badasie and Schulze (2018)	South Africa	Participatory action research	Science professional development (Biology)	14 teachers	• Observations from participants and field notes • Reflection meetings • Interviews • Focus groups • Document analysis	Qualitative

(*Continued*)

Table 2. (Continued).

No.	Articles	Jurisdictions	Methodological choice of action research	Action plan (Science topic)	Participants	Data collection methods	Data analysis
7	Blanchet-Cohen and Di Mambro (2015)	Canada	Participatory action research	Green Committee (Biology)	19 grade 4–6 children (9–11 years old)	• Field notes from participants • Transcriptions of research sessions • Questionnaires • Focus groups	Qualitative
8	Buck et al. (2014)	United States	Participatory action research	Collaborative problem-based learning (Biology, Chemistry and Physics)	30 grade 3–6 children (8–12 years old)	• Attitudes towards science questionnaires • Attractions and self-efficacy in science scales • Surveys • Focus group interviews	Quantitative and qualitative (mixed methods)
9	Coban and Coştu (2021)	Turkey	Classroom action research	Biomimicry Teaching Approach (Biology)	19 grade 5 children (10 years old)	• Children's assessments • Children's projects • Children's presentations	Qualitative
10	Emembolu et al. (2020)	United Kingdom	Exploratory action research	Career-driven STEM (Biology, Chemistry and Physics)	377 grade 1–4 children (7–10 years old)	• STEM Career Knowledge and Aspirations Tool	Quantitative
11	Harper (2017)	United States	Collaborative action research	Cross-cultural learning community (Biology and Physics)	9 grade 4–5 children (9–11 years old)	• Video transcripts of the activities • Interviews • Researcher's reflective journal • Focus group discussions	Qualitative
12	Hawamdeh (2020)	Jordan	Classroom action research	Role-playing strategy (Physics)	Grade 4 children (9–10 years old)	• Worksheets • Children's reflections • Focus group interviews	Quantitative and qualitative (mixed methods)

(*Continued*)

Table 2. (Continued).

No.	Articles	Jurisdictions	Methodological choice of action research	Action plan (Science topic)	Participants	Data collection methods	Data analysis
13	Hendrix et al. (2012)	United States	Classroom action research	Creative drama (Physics)	38 grade 4 and 5 children (9–11 years old)	• Tests • Attitude surveys • Daily field notes	Quantitative and qualitative (mixed methods)
14	Jones (2018)	United States	Classroom action research	Concept of definition word map (Biology)	37 grade 4 children (9–10 years old)	• Tests • Transcriptions of focus groups • Children's work • Teachers' observations	Quantitative and qualitative (mixed methods)
15	Kellner and Attorps (2020)	Sweden	Collaborative action research	School-university collaboration (Biology)	9 teachers 2 researchers 2 researchers	• Focus group interviews	Qualitative
16	Kucuk (2022)	Turkey	Exploratory action research	Creative drama (Biology)	42 grade 5 children (11–12 years old)	• Open-ended questionnaires • Tests	Quantitative and qualitative (mixed methods)
17	Long and Bae (2018)	Singapore	Collaborative action research	Inquiry-based lessons (Information not available)	2 teachers	• Interviews • Lesson observations • Lesson plans • Teachers' timetables	Qualitative
18	Macanas and Rogayan (2019)	Philippines	Classroom action research	Sci-vestigative Pedagogical Strategy (Chemistry)	59 grade 6 children (11–12 years old)	• Tests • Written works • Performance tasks	Quantitative
19	Mohd Salleh and Mat Noor (2015)	Malaysia	Participatory action research	Easy Erase Response Board (Biology)	10 grade 4 children (10 years old)	• Structured and unstructured observations • Self-assessment scales • Questionnaires	Quantitative and qualitative (mixed methods)
20	Mulyanto et al. (2020)	Indonesia	Classroom action research	Discovery e-learning (Physics)	36 grade 5 children (10–11 years old)	• Observations • Children's assessments	Quantitative and qualitative (mixed methods)
21	Nurmi et al. (2018)	Indonesia	Classroom action research	Visual multimedia (Information not available)	30 grade 3 children (8–9 years old)	• Observations • Tests	Quantitative and qualitative (mixed methods)

(*Continued*)

Table 2. (Continued).

No.	Articles	Jurisdictions	Methodological choice of action research	Action plan (Science topic)	Participants	Data collection methods	Data analysis
22	Phoon et al. (2020)	Brunei	Classroom action research	Comic book (Biology)	18 grade 5 children (10–11 years old)	• Observations • Interviews • Tests	Quantitative and qualitative (mixed methods)
23	Phoopanna and Nuangchalerm (2022)	Thailand	Classroom action research	Community-based science learning (Chemistry)	12 grade 5 children (10–11 years old)	• Lesson plans • Tests • Questionnaires • Interviews with children	Quantitative and qualitative (mixed methods)
24	Piliouras and Evangelou (2012)	Greece	Collaborative action research	Cross-border strategies (Chemistry)	48 grade 5 children (10–11 years old)	• Field notes • Videos of teachers' lessons • Children's protocols • Teacher's reflective diaries	Quantitative and qualitative (mixed methods)
25	Rogayan and Macanas (2020)	Philippines	Classroom action research	AGHAMIC Action Approach (Chemistry)	47 grade 6 children (11–12 years old)	• Tests • Written works • Performance tasks	Quantitative
26	Saleh et al. (2020)	Indonesia	Classroom action research	Problem-based learning (Information not available)	25 grade 4 children (89–10 years old)	• Observations • Tests	Quantitative and qualitative (mixed methods)
27	Syawaludin et al. (2019)	Indonesia	Classroom action research	Interactive multimedia based on augmented reality (Physics)	28 grade 5 children (10–11 years old)	• Observations • Tests	Quantitative and qualitative (mixed methods)
28	Tekbiyik and Çelik (2019)	Turkey	Classroom action research	Education for sustainable development (Biology)	15 grade 3 children (9–10 years old)	• Rhetorical and analytical discussions • Mind maps • Drawings	Qualitative

(*Continued*)

Table 2. (Continued).

No.	Articles	Jurisdictions	Methodological choice of action research	Action plan (Science topic)	Participants	Data collection methods	Data analysis
29	Uştu et al. (2022)	Turkey	Participatory action research	Integration of Arts into STEM Education (Physics and chemistry)	4 teachers153 grade 4 children (10–11 years old) 153 grade 4 children (10–11 years old)	• Diaries • Interviews • Focus group interviews • Field notes • Activity plans • Photographs • Video recordings • Children's products	Qualitative
30	Wang et al. (2012)	Taiwan	Collaborative action research	Blogs, MS PowerPoint and the Internet (Biology)	32 grade 6 children (11–12 years old)	• Teachers' observations • Questionnaires • Interviews • Parents' feedback • Children's work	Quantitative and qualitative (mixed methods)
31	Yavuz and Duban (2021)	Turkey	Classroom action research	STEM implementations (Physics and Chemistry)	26 grade 4 children (10–11 years old)	• Tests • Interviews	Quantitative and qualitative (mixed methods)
32	Yeşilyurt et al. (2020)	Turkey	Classroom action research	Environmental education (Biology)	38 grade 2 children (8–9 years old)	• Personal forms • Pictures • Interviews • Observations	Qualitative
33	Yuliati et al. (2019)	Indonesia	Classroom action research	Guided inquiry model with macromedia flash (*Information not available*)	30 grade 5 children (10–11 years old)	• Observations • Tests • Interviews • Field notes	Quantitative and qualitative (mixed methods)

The selected articles involved various participants from different backgrounds. A total of 89 researchers, 20 parents, 40 teachers and 1,379 children participated in the selected 33 studies. The children who participated in these studies can be further enumerated according to their grade levels. Most studies were conducted with grade 4 and grade 5 children (for each grade: $n = 12$), followed by grade 6 ($n = 7$), grade 3 ($n = 4$), grade 1 and grade 2 ($n = 2$). All of the studies clearly practised different data analysis methods, with most studies analysed using mixed methods ($n = 17$), qualitative methods ($n = 12$) and quantitative methods ($n = 4$). In conjunction, the researchers applied various data collection methods in the reviewed studies. Most studies used interviews and discussions ($n = 24$), followed by observations ($n = 18$), work produced by children ($n = 16$), pre-tests and post-tests ($n = 15$), questionnaires and surveys ($n = 13$), field notes/diaries ($n = 11$), document analysis ($n = 7$) and photos/pictures ($n = 2$).

Quality of action research studies in the context of primary science education

We used the Quality Assessment of Teacher Research, adapted from Leuverink and Aarts' (2019) study, to determine the quality of all 33 selected action research articles. The study aims to investigate the standards used to evaluate teacher research to promote professional growth and school development. We also reviewed each article based on three types of validity in action research: outcome, process and democratic validity, adapted from Herr and Anderson (2015). All three types of validity were graded on a seven-point scale ranging from insufficient to excellent, thus further reflecting the international scoring system with seven points (Leuverink and Aarts 2019) (see Table 3). The scores from all reviewers were then calculated to determine the average value of each validity. However, catalytic and dialogic validity were discarded in the quality appraisal step in this systematic review as they cannot be assessed by reviewing the research papers alone. Rather, to be properly executed, more information would be required from the authors (Leuverink and Aarts 2019).

The criterion for outcome validity must fulfil the three requirements: research questions are addressed, solutions for the problems are provided, and new research questions are developed (Leuverink and Aarts 2019). On average, this systematic review recorded outcome validity with a good score value of 5.1. The analysis (see Table 4) shows that five articles nearly achieved an excellent score, all achieving 6.5 (Acharya et al. 2022; Blanchet-Cohen and Di Mambro 2015; Buck et al. 2014; Coban and Coştu 2021; Piliouras and Evangelou 2012), and only one article was less than sufficient, with a poor score of 2.5 (Yuliati et al. 2019). The poor score was due to the authors providing inadequate

Table 3. Validity of action research scoring system (Leuverink and Aarts 2019).

Score	Meaning
7	Excellent
6	Very good
5	Good
4	More than sufficient
3	Sufficient
2	Poor
1	Insufficient

Table 4. The quality of action research studies.

No.	Articles	Outcome validity	Process Validity	Democratic validity
1	Acharya et al. (2022)	6.5	7.0	7.0
2	Alkiş Küçükaydin (2018)	5.5	4.0	4.0
3	Attorps and Kellner (2017)	6.0	6.5	6.0
4	Azainil et al. (2019)	4.5	3.0	3.0
5	Aziz et al. (2013)	4.0	3.0	3.0
6	Badasie and Schulze (2018)	5.0	5.0	6.5
7	Blanchet-Cohen and Di Mambro (2015)	6.5	6.5	6.5
8	Buck et al. (2014)	6.5	6.5	7.0
9	Coban and Coştu (2021)	6.5	5.0	4.0
10	Emembolu et al. (2020)	6.0	6.0	4.5
11	Harper (2017)	5.0	5.5	6.5
12	Hawamdeh (2020)	4.5	3.5	4.0
13	Hendrix et al. (2012)	5.5	4.5	4.5
14	Jones (2018)	5.5	5.0	4.0
15	Kellner and Attorps (2020)	5.5	6.5	6.5
16	Kucuk (2022)	5.5	3.5	3.5
17	Long and Bae (2018)	6.0	5.5	5.0
18	Macanas and Rogayan (2019)	5.5	4.5	3.0
19	Mohd Salleh and Mat Noor (2015)	5.5	4.5	4.0
20	Mulyanto et al. (2020)	4.0	3.0	3.0
21	Nurmi et al. (2018)	4.0	2.5	3.0
22	Phoon et al. (2020)	4.0	3.0	3.0
23	Phoopanna and Nuangchalerm (2022)	3.5	4.0	2.5
24	Piliouras and Evangelou (2012)	6.5	5.5	6.0
25	Rogayan and Macanas (2020)	5.5	4.0	3.5
26	Saleh et al. (2020)	4.0	3.5	3.0
27	Syawaludin et al. (2019)	3.5	3.5	3.5
28	Tekbiyik and Çelik (2019)	4.5	4.0	2.5
29	Uştu et al. (2022)	6.0	6.0	7.0
30	Wang et al. (2012)	5.5	6.0	6.0
31	Yavuz and Duban (2021)	4.0	4.0	3.0
32	Yeşilyurt et al. (2020)	5.0	4.5	4.0
33	Yuliati et al. (2019)	2.5	2.5	3.0
	Average value	5.1	4.6	4.4

information concerning solutions and recommendations; thus, no new research questions were generated from the study.

Herr and Anderson (2015) highlighted that process validity must address the contentious issue of what counts as evidence to support an argument. To achieve this, four criteria must be assessed. The report must therefore: employ suitable research methods, implement triangulation, be transparent, and adopt a process of continuous reflection (Leuverink and Aarts 2019). On average, process validity was graded as 4.6 on average for all the reviewed articles. Only one article achieved an excellent score of 7.0 (Acharya et al. 2022) and two articles a poor score of 2.5 (Nurmi et al. 2018; Yuliati et al. 2019). The low score was due to the overall unstructured nature of the report, as no information on data analysis and no process of continuous reflection were mentioned.

Democratic validity reflects the extent to which research is conducted in partnership with all stakeholders to address the investigated problem (Herr and Anderson 2015). On average, democratic validity was graded with 4.4, indicating a more than sufficient score. The stakeholders involved in these reviewed studies included primary school children, teachers, administrative staff, researchers and parents. Three articles achieved an excellent score of 7.0 (Acharya et al. 2022; Buck et al. 2014; Uştu, Saito, and Mentiş Taş 2022) because the stakeholders' viewpoints were consulted throughout the study's design phase, incorporating them as study participants and allowing them to test interventions in practice (Leuverink and Aarts 2019). In contrast, the two articles that attained a poor score of 2.5 (Phoopanna and Nuangchalerm 2022; Tekbiyik and Çelik 2019) involved the stakeholders (primary children) as informants only.

Effects of the employed action research methodology on children's learning in science

The connection among all the 33 action research studies is demonstrated by their effects on children's learning in science (as shown in Table 5). Four themes were garnered from the analysed studies: teachers' strategies and professional development, children's scientific skills, children's conceptual understanding, and children's interest in and attitudes towards science. The selected articles that accumulated the most observed effects on children's learning in science were children's scientific skills ($n = 10$), followed by teachers' strategies and professional development, children's conceptual understanding [with the same number of articles for each ($n = 9$)], and children's interest in and attitudes towards science ($n = 8$). Most articles had a single effect on children's learning in science ($n = 30$), while the remaining three had multiple impacts.

An increasing body of literature is highlighting that action research contributes to teachers' professional development. A growing number of teachers have incorporated action research into their practice as it is an excellent technique for them to grow as professionals and enhance their teaching practice (Efron and Ravid 2013; McNiff 2017). As Table 5 shows, nine reviewed studies showed the positive impact of the employed action research strategies on teachers' strategies and professional development. Action research projects in collaboration with universities provide primary science teachers with the opportunity to boost their professional development by shifting from an obstinate lecturing pedagogy to student-centred activities (Acharya et al. 2022), to designing the science curriculum (Attorps and Kellner 2017; Kellner and Attorps 2020), implementing pertinent learning theories (Badasie and Schulze 2018) and enhancing students' perception of scientific inquiry (Long and Bae 2018). Furthermore, the applied action plan acts as the primary science teacher's strategy in the classroom, which is offset by a specific approach: scientific teaching (Coban and Coştu 2021), cross-cultural pedagogy (Piliouras and Evangelou 2012), arts in science learning (Uştu, Saito, and Mentiş Taş 2022) and technology-integrated inquiry learning (Wang et al. 2012).

The positive effects on children's scientific skills were consistent with the science education strategy of inquiry-based teaching and learning that incorporates numerous systematic procedures of scientific activity (Cairns, Dickson, and McMinn 2021). The practising of action research projects in primary science education settings improved children's reasoning skills (Aziz, Shamsuri, and Damayanti 2013; Harper 2017; Syawaludin, Gunarhadi, and Rintayati 2019) and environmental skills (Tekbiyik and Çelik 2019; Yeşilyurt, Balakoğlu, and Erol 2020). Meanwhile, other scientific skills enhanced through the numerous action plans implemented in primary science included children's autonomy (Blanchet-Cohen and Di Mambro 2015), analytical skills (Hawamdeh 2020), cognitive

Table 5. Measured effects on children's learning in science.

No.	Articles	Teachers' strategies and professional development	Children's scientific skills	Children's conceptual understanding	Children's interest in and attitudes towards science
1	Acharya et al. (2022)	✓			
2	Alkiş Küçükaydin (2018)				✓
3	Attorps and Kellner (2017)	✓			
4	Azainil et al. (2019)			✓	✓
5	Aziz et al. (2013)		✓		
6	Badasie and Schulze (2018)	✓			
7	Blanchet-Cohen and Di Mambro (2015)		✓		
8	Buck et al. (2014)				✓
9	Coban and Coştu (2021)	✓			
10	Emembolu et al. (2020)				✓
11	Harper (2017)		✓		
12	Hawamdeh (2020)		✓		
13	Hendrix et al. (2012)			✓	✓
14	Jones (2018)			✓	
15	Kellner and Attorps (2020)	✓			
16	Kucuk (2022)		✓		
17	Long and Bae (2018)	✓			
18	Macanas and Rogayan (2019)			✓	
19	Mohd Salleh and Mat Noor (2015)				✓
20	Mulyanto et al. (2020)		✓		
21	Nurmi et al. (2018)			✓	
22	Phoon et al. (2020)			✓	✓
23	Phoopanna and Nuangchalerm (2022)		✓		
24	Pilouras and Evangelou (2012)	✓			
25	Rogayan and Macanas (2020)			✓	
26	Saleh et al. (2020)			✓	
27	Syawaludin et al. (2019)		✓		
28	Tekbiyik and Çelik (2019)		✓		
29	Uştu et al. (2022)	✓			
30	Wang et al. (2012)	✓			
31	Yavuz and Duban (2021)				✓
32	Yeşilyurt et al. (2020)		✓		
33	Yuliati et al. (2019)			✓	
	Total	9	10	9	8

structures (Kucuk 2022), critical thinking skills (Mulyanto, Sadono, and Koeswanti 2020) and scientific habits of mind (Phoopanna and Nuangchalerm 2022).

Teaching for conceptual understanding is fundamental because when children use a concept in a different setting, describe or define it in their own terms, make a model of it, or find an appropriate metaphor to describe it, their understanding of the subject is boosted (Konicek-Moran and Keeley 2015). Nine of the reviewed studies showed an increment in children's conceptual understanding as a result of the employed action research projects. Quantitative studies and a number of mixed methods studies examined the effects of action research projects on the conceptual understanding of primary children by comparing the increment of scores, pre-test and post-test (Hendrix, Eick, and Shannon 2012; Jones 2018; Macanas and Rogayan 2019; Phoon et al. 2020; Rogayan and Macanas 2020). The remaining mixed methods studies demonstrated an improvement in children's conceptual understanding with an increase in children's scores through each action research cycle (Azainil et al. 2019; Nurmi et al. 2018; Saleh, Ahda, and Fitria 2020; Yuliati et al. 2019).

Motivation and interest play a crucial role in science teaching and learning and can enhance children's participation and facilitate their knowledge acquisition (Kılıç, Kılıç, and Akan 2021). Concerning children's interest in and attitudes towards science, eight articles examine different areas: children's motivation and interest, children's attitudes towards science, and children's perception. With regards to motivation and interest, the employed action research studies showed an increase in children's motivation through each action research cycle (Azainil et al. 2019), and STEM activities attracted children's interest the most (Yavuz and Duban 2021). Concerning attitudes towards science, the implemented action plans shifted children's attitudes toward science learning (Buck et al. 2014; Hendrix, Eick, and Shannon 2012; Phoon et al. 2020), and improved children's response to science (Mohd Salleh and Mat Noor 2015). Lastly, in relation to science perception, the studies showed that the primary children left with a more positive perception of scientists (Alkiş Küçükaydin 2018) and science career knowledge (Emembolu et al. 2020).

Conclusions

This systematic literature review of 33 action research studies in the primary school setting offers four main conclusions and implications for future research and practice. First, most studies have chosen to utilise mixed methods analysis when evaluating classroom action research, with interviews and discussions being their primary methodological choice. In contrast, we recognised the benefits of employing interpretative and naturalistic approaches to data collection or leveraging readily available data such as students' artefacts and teaching resources. These approaches serve to minimise the workload of teachers who are simultaneously engaged in both teaching and research activities. A similar perspective was extensively deliberated by Cochran-Smith and Lytle (1990), who emphasised that teacher research focuses on the actions of teachers rather than solely relying on their professional judgments. Their work sought to capture the nuances of teaching by identifying specific behaviours through the unintentional data collected across different classrooms. Thus, primary school science teachers were encouraged to practise classroom action research within their own classroom settings, naturally as a stepping stone to connecting theory to practice (Mertler 2019), which resonates with our approach in this review.

Secondly, this review stressed that researchers should evaluate the outcome, process and democratic validity of their action research studies, thus improving their quality. A valid and high-quality teacher action research study plays a pivotal role in fostering teachers' professional growth and development (Mat Noor et al., 2023). By actively engaging in rigorous and valid research practices, teachers have the opportunity to delve deeper into their instructional approaches, student learning processes, and the consequences of their actions. As highlighted by Feldman (2007), the ultimate goal of action research is to drive improvements in teachers' practices and the educational environments in which both students and teachers are immersed. Therefore, it is imperative for academic researchers and teacher-researchers to produce better quality action research studies, by providing professional development programmes to primary school science teachers on the implementation of high-quality teacher research.

Thirdly, this systematic review offers various action plans that cover different science domains and positively impact children's learning in science. Primary school science teachers need incremental guidance in the planning and implementation of science-related lesson plans and classroom activities, discovering more about how children think and comprehend scientific ideas (Kamarudin, Mat Noor, and Omar 2022; Muhamad Dah et al. 2023). Through valid and high-quality action research studies, readers gain a comprehensive understanding of the process and implementation of teacher research, moving beyond a sole focus on the results (Bradbury et al. 2019). This stands in contrast to the majority of published articles in science and primary education journals, which often emphasise outcomes alone. The present study specifically examines science domains that have a positive influence on children's science learning. By mapping what works best in terms of pedagogy within primary science classrooms, the review presents actionable insights for science teachers. These insights can be utilised as a blueprint for replicating successful action plans within their own classroom settings, thereby enhancing teaching and learning processes.

Finally, based on this review, we observed that the process of utilising teacher action research in collaboration with external university researchers as critical friends (see Mat Noor and Shafee 2021) enhanced teachers' professional development. External researchers provide specialised knowledge and learning opportunities for primary science teachers to widen the implementation of pedagogical concepts and their diagnosis, to improve personal skills, autonomy, and self-efficacy (Laudonia et al. 2018). In addition, this teacher-researcher collaboration promoted the advancement of high-quality action research. By working together, an insider-outsider partnership was developed, which broke down any power hierarchies between teachers and researchers, allowing both to share their expertise and resources, provide feedback, and support each other (Herr and Anderson 2015). This review offers concrete examples of action plan teaching and learning strategies for primary science education, highlighting the complex epistemic nature of action research. By engaging in action research and employing various teaching and learning strategies, primary science teachers can enhance their research skills. This in turn can benefit children, enhancing their knowledge acquisition and allowing them to work towards the ultimate goal of scientific literacy (Mat Noor 2022).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Hadiah Latihan Persekutuan (HLP) (literally translated as 'Federal Training Prizes') from the Ministry of Education, Malaysia.

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Appendix

Appendix 1. Articles selected in this review

				Sources						
No.	Authors	Year	Journal	Scopus	Web of Science	ERIC	Google Scholar	Action Research Journals	Science Education Journals	Primary Education Journals
1	Acharya, K. P., Budhathoki, C. B., Bjønness, B., & Devkota, B.	2022	Educational Action Research				✓	✓		
2	Alkiş Küçükaydin M.	2018	Asia-Pacific Forum on Science Learning and Teaching	✓						
3	Attorps, I., & Kellner, E.	2017	International Journal of Science and Mathematics Education		✓				✓	
4	Azainil, Jumini, Haryaka, U., Komariyah, L., & Ramadiani.	2019	International Journal of Innovation, Creativity and Change	✓			✓			
5	Aziz, Z., Shamsuri, S. M., & Damayanti, L.	2013	Review of European Studies	✓						
6	Badasie, R. G., & Schulze, S.	2018	Journal For New Generation Sciences		✓					
7	Blanchet-Cohen, N., & Di Mambro, G.	2015	Action Research					✓		
8	Buck, G., Cook, K., Quigley, C., Prince, P., & Lucas, Y.	2013	Elementary School Journal	✓	✓		✓			✓
9	Coban, M., & Coştu, B.	2021	Journal of Biological Education	✓	✓					
10	Emembolu, I., Padwick, A., Shimwell, J., Sanderson, J., Davenport, C., & Strachan, R.	2020	International Journal of Science Education	✓	✓				✓	
11	Harper, S. G.	2017	International Journal of Science Education	✓	✓				✓	
12	Hawamdeh, A. A. A.	2020	Action Research and Innovation in Science Education					✓		
13	Hendrix, R., Eick, C., & Shannon, D.	2012	Journal of Science Teacher Education	✓	✓	✓	✓		✓	
14	Jones, K.	2018	Journal of Teacher Action Research					✓		
15	Kellner, E., & Attorps, I.	2020	Teacher Development		✓					

(*Continued*)

No.	Authors	Year	Journal	Sources: Scopus	Web of Science	ERIC	Google Scholar	Action Research Journals	Science Education Journals	Primary Education Journals
16	Kucuk, A.	2022	Journal of Turkish Science Education	✓						
17	Long, S. C. J., & Bae, Y.	2018	Asia-Pacific Science Education	✓						
18	Macanas, G. A., & Rogayan, D. V.	2019	Participatory Educational Research	✓						
19	Mohd Salleh, N., & Mat Noor, M. S. A	2015	Procedia – Social and Behavioral Sciences				✓			
20	Mulyanto, B. S., Sadono, T., & Koeswanti, H. D.	2020	Journal of Educational Research and Evaluation				✓			
21	Nurmi, N., Putra, H., Nursida, P., Mahbubah, K., & Hermita, N.	2018	Journal of Teaching and Learning in Elementary Education				✓			
22	Phoon, H.-Y., Roslan, R., Shahrill, M., & Said, H. M.	2020	Formatif: Jurnal Ilmiah Pendidikan MIPA				✓			
23	Phoopanna, A., & Nuangchalerm, P.	2022	Jurnal Penelitian dan Pembelajaran IPA		✓					
24	Piliouras, P., & Evangelou, O.	2012	Research in Science Education	✓	✓	✓			✓	
25	Rogayan, D. V., & Macanas, G. A.	2020	Journal for the Education of Gifted Young Scientists	✓						
26	Saleh, A., Ahda, Y., & Fitria, Y.	2020	Jurnal Basicedu				✓			
27	Syawaludin, A., Gunarhadi, & Rintayati, P.	2019	Jurnal Pendidikan IPA Indonesia	✓						
28	Tekbiyik, A., & Çelik, M.	2019	Journal of Education in Science, Environment and Health			✓				
29	Uştu, H., Saito, T., & Mentiş Taş, A.	2022	Systemic Practice and Action Research		✓					
30	Wang, C. hsing, Ke, Y. T., Wu, J. T., & Hsu, W. H.	2012	Journal of Science Education and Technology	✓	✓				✓	
31	Yavuz, Ü., & Duban, N. Y.	2021	International Technology and Education Journal			✓				
32	Yeşilyurt, M., Balakoğlu, M. Ö., & Erol, M.	2020	Qualitative Research in Education			✓				
33	Yuliati, Y., Saputra, D. S., Rachmadtullah, R., Rasmitadila, & Iasha, V.	2019	International Journal of Scientific and Technology Research	✓						