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Implementation of case-based learning in science education: A systematic review*

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**This paper is a preliminary study of the thesis.*

ABSTRACT

Case-Based Learning (CBL) in science education has developed rapidly. This paper reviews the literature on trends in implementing CBL in science education. For this systematic review, we followed the recommendation of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. Data were obtained from the ERIC, Scopus, and Google Scholar databases by taking scientific articles from reputable international journals with a Scopus Q1-Q4 index and impact factor ranging from 0.040 to 3.092, which is the main indicator of choosing quality of journal articles. Articles were searched using titles and keywords "Case-Based or Case Method or Science Education" from 2012 to 2022. The search yielded 1183 articles, and the selection results were 52 articles for review. The study found that CBL was represented mostly in three learning approaches, namely CBL-IBL, CBL-PBL, CBL-PjBL, and the rest being CBL-Blended, CBL-Oline, and CBL-Collaborative. Case-based applications in science education were dominated by health (58%), chemistry (35%), physics (1%) and biology (6%). The reviewed studies encountered some difficulties in implementing CBL. One of them is that solving the problem takes a long time. This review revealed case-based approach to be appropriate to be implemented in an active learning activity based on real-life context.

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Introduction

One of the critical issues in the dynamics of science learning is the presentation of the context of facts to learners. Current trends show their difficulty in creating relevance between the knowledge of science they learn and the daily life issues (Akbulut & Demir, 2020). Researchers and practitioners of science education recognise that the lack of pupil motivation and interest in learning science is partly due to the vast scope of science material that must be studied according to the curriculum and which is oriented toward the final formal assessment (Akbulut & Hill, 2020; Thibaut & Schroeder, 2020).

In science learning, it was also found that learning emphasizes mastery of a number of facts and concepts and does not facilitate students to have comprehensive learning outcomes (Çam & Geban, 2017; Mardiani et al., 2022; Wikanta & Susilo, 2022). The outcome of learning tends to be limited to mastery of concepts without the ability to higher order thinking (Günter et al., 2019) & (Pratiwi, Rahayu, & Fajaroh, 2016). There are several significant issues about how science is traditionally taught, such as over-emphasising science content, the absence of a clear purpose of science learning because the curriculum is taught as an aggregation of isolated facts that do not facilitate the formation of meaningful relationships between facts, lack of transfer of problem-solving skills, lack of relevance to learners' lives, and inadequate emphasis on the skills necessary to study science further (Bortnik et al., 2021). Science in specific contexts can increase student engagement in learning and has become increasingly popular in the last five years (Podschuweit & Sascha, 2018) & (Nida, Rahayu, & Eilks, 2020).

In the learning process, context can be used as a starting point for asking questions related to science, applying and deepening science, and developing competencies such as argumentation about science (Broman & Parchmann, 2014; Tsao et al., 2022; Wanloh & Nuangchalerm, 2022). Context-based problems are usually not simple questions that can be answered with rote learning or algorithmic scripts but require different problem-solving skills (Zhao et al., 2020) & (Cahyarini, Rahayu, & Yahmin, 2016). Solving problems embedded in an authentic context often implies specific challenges and demands to the learner's abilities (Yang et al., 2019) & (Yuliastini et al., 2018). Thus, the learning scenario must be related to the context or case associated with real life (Günter & Alpat, 2019).

Creating a context for learning is crucial because it can be used as a tool to make science learning more relevant to learners' lives, direct learning outcomes such as appreciation of the nature of science (NOS), increase dialogue and argumentation, improve pupils' ability to evaluate scientific information (van Dulmen et al., 2022; Kang, 2022). Contexts can be personal, local/national, or global issues (Szozda et al., 2022). These issues can be in the present (contemporary), the past related to understanding science and technology, or controversial socio-scientific issues (SSI) (Szozda et al., 2023).

One approach that is often used to solve problems in science learning is Case-Based Learning. The urgency of implementing CBL in science learning is to provide a practical model for students to connect learning chemistry content with practice and help them improve their ability to collaborate, think critically, and solve problems (Günter et al., 2019). Case-based learning has been delivered in various curricula, and student feedback indicates that CBL significantly improves students' understanding of biology lessons in college (Naping & Musywirah, 2019) Interest in studying physics through CBL makes learners more critical in participating in learning and directly influences the improvement of their scientific reasoning skills college students (Wati & Sunarti, 2020; Mardiani et al., 2022).

Many studies have revealed that getting proper guidance on the implementation of the necessary cases (Naping & Musywirah, 2019). CBL can increase motivation to learn chemistry and learners' attitude toward chemistry (Naping & Musywirah, 2019)CBL can facilitate for students to conduct experiments with biochemistry laboratory manipulating virtual equipment on a screen (Günter et al., 2019; Günter & Alpat, 2019). CBL can introduce the principle of green chemistry through case-based learning modules on environmental chemistry courses at varsity level (Thibaut & Schroeder, 2020; Ballard & Mooring, 2021). Lecturers use strictly for tertiary level and students, however, still have difficulties in the process of implementing CBL, such as designing cases to be used (Çam & Geban, 2017), developing learning goals clearly and systematically by workloads and time limits (Bi et al., 2019 & Jamari et al., 2018), articulating and summarising conclusions clearly and concisely according to the given topic (Suwono et al., 2017). Of these problems, the impact for teachers and researchers is that it can provide an overview of the application of CBL in science learning so far. Thus, teachers are trained to use CBL through in-service workshops so that they can change teachers' mindset about applying CBL to be better prepared to apply effective CBL to science learning. Based on these problems, a systematic review of the practical CBL approach is needed to be implemented as one of the promising learning strategies in science learning.

Theoretical Framework

Defining Case-Based Learning

Case-Based Learning (CBL) is fundamentally learner-centred, acknowledging the importance of actively engaging them in their own learning (Thistlethwaite et al., 2012; Allchin, 2013), encouraging them to study independently, and encouraging them to orient themselves to realistic and specific situations (Bi et al., 2019). Learners focus on cases, engage in independent learning, scientific inquiry, and collaboration with peers, develop critical thinking and problem-solving abilities, and integrate theory into practice (Jamari et al., 2018; Bi et al., 2019). Case-based applications are used to demonstrate theory in practice and give practical examples, facilitate problem-solving and decision-making by providing contexts, encourage critical analysis and discussion, develop critical and creative thinking skills, and provide an opportunity to evaluate problem solving (Günter et al., 2019). CBL learning outcomes relate to students' ability to sort out factual data, apply analytical tools, articulate problems, reflect on their relevance and experiences, conclude that they can relate to new situations, identify problems by connecting the meaning of context with their own lives, and asking questions and formulating strategies to analyse data and come up with solutions (Alt et al., 2020; Günter & Alpat, 2019).

Review Objectives

The focus of this review study is to compare previously applied CBL learning syntax and to analyse the application of CBL approaches in science learning. The potential contribution generated from this review study was to provide recommendations related to CBL types that are effectively applied to accommodate difficulties in implementing the CBL approach. The problem formulation of this literature study was as follows:

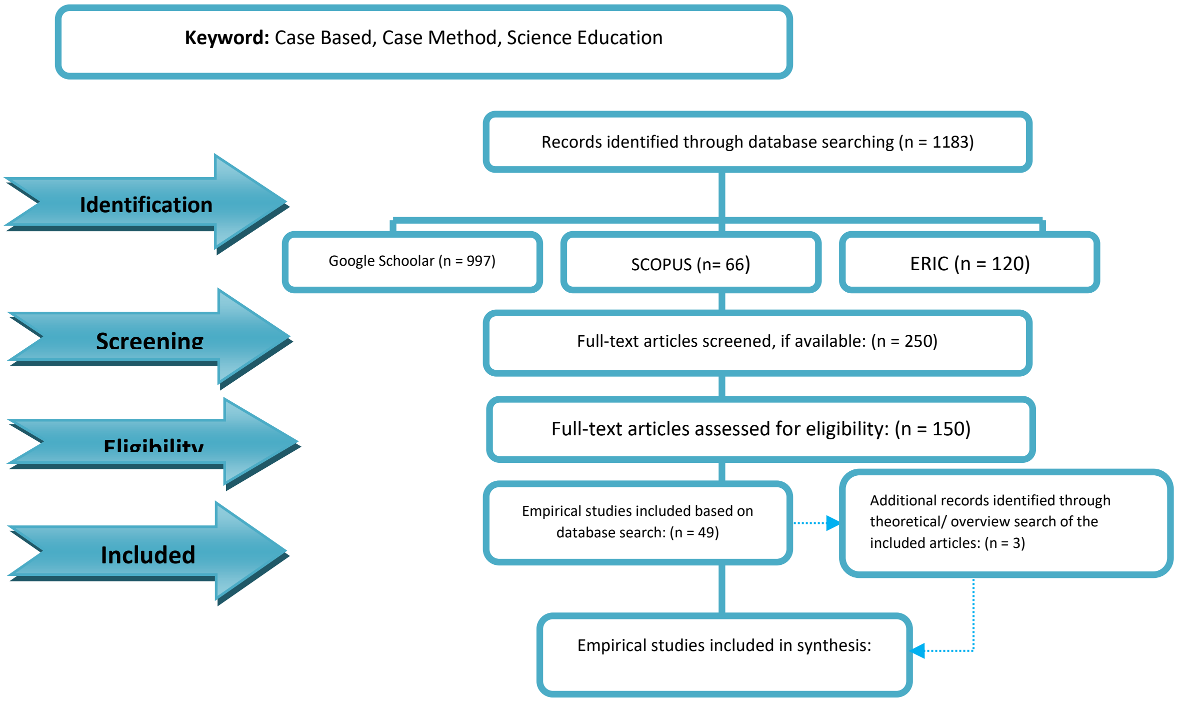
a) How do practitioners implement the CBL approach in science education?
b) How much frequency is the use of CBL variants with disciplines in science education?
c) What difficulties were found while implementing the CBL approach in science education?

Methods

This study used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) framework. PRISMA is a tool and guide used to evaluate systematic reviews and meta-analyses (Zarate et al., 2022). The reading text can be articles, books, transcripts, notes, magazines, newspapers, inscriptions, agendas, and meeting minutes (Arikunto, 2016). The literature study took data from scientific articles from reputable International Journals with the Q1-Q4 Scopus index with an impact factor (IF) ranging from 0.040 to 3.092, which is the main indicator of choosing quality journal articles. The databases used ERIC, Scopus, and Google Scholar through the Publish of Perish application using search keywords: 1) Case-Based, 2) case method and 3) science education. Article searches were limited to the last ten years, from 2012 to 2022. The following is a flowchart illustrating the mapping of the selection of relevant articles for systematic review.

Figure 1

Flowchart Illustrates the Mapping of the Selection of Relevant Articles For Systematic Review



Note. Adoption from (Zarate et al., 2022).

The PRISMA flow chart is shown in Figure 1. They were checked for duplicates with Mendeley's "check for duplicates" algorithm; suggested duplicates were manually removed afterwards. The 856 articles remaining were then screened for eligibility. Then whether they reported on the application of case-based learning, and then what were the findings of the study.

Finally, we evaluated the research problems, objectives, and methods, including research design, targets, and topics of the studies. We excluded 250 notes by title or abstract filtering because they did not focus on learning science 150 remaining articles were checked for full-text availability. We excluded 30 articles because no full text was available. Other 40 articles were excluded based on full-text filtering (only abstract available without full-text). We then assessed 80 articles identified as potentially relevant for review for feasibility by focusing on their methodology. We used Microsoft Excel as a data management tool to classify and analyse full-text articles.

The assessment of 80 articles has been completed by three researchers individually (initial inter-rater agreement of 82%). All studies are then discussed until 100% agreement on which analysis to include in the review was reached. As a result, 31 articles were excluded based on exclusion criteria. A detailed review of the articles excluded based on exclusion criteria is presented in Table 1. We also performed a backward and forward search on the 31 published theoretical articles and summaries of this previous review. In addition, we identified two other articles that matched the eligibility criteria. Thus, 52 empirical articles were included in this systematic review. Two researchers conducted the encoding of articles on critical variables individually, with the direct inter-rater agreement of 98% as the variable that we value can be drawn from the article objectively.

Eligibility Criteria for Articles

After reviewing abstracts and keywords, 1183 articles were obtained from database sources and then filtered based on five eligibility criteria: the articles must be written in English, be peer-reviewed, be related to a case-based and case method. Applying these eligibility criteria left 52 articles for further review, including 49 articles from empirical database studies and three from additions identified through theoretical searches/overviews. The results can be seen in Table 1.

Table 1

Article Selection Results

National of context	Reviewed studies	Name of journal	Index scopus
Turkey	Çam, A., & Geban, Ö. (2017)	Research in Science & Technological Education	Q1
Turkey	Günter & Alpat (2019)	Research in Science Education	Q1
Korea	Ha (2020)	Nurse Education Today	Q1
China	Zhao et al. (2020)	BMC Medical Education	Q1
Germany	Hempel et al. (2016)	European Journal of Emergency Medicine	Q1
Turkey	Yalçınkaya et al. (2012)	Research in Science and Technological Education	Q1
Belgium	Baeten et al. (2013)	European Journal of Psychology of Education	Q1
China	Hong & Yu (2017)	International Journal of Nursing Studies	Q1
South Korea	Yoo & Park (2014)	Nurse Education Today	Q1
USA	Krupat et al. (2016)	Academic Medicine	Q1
Spain	Raurell-Torredà et al. (2015)	Journal of Nursing Scholarship	Q1
Iran	Gholami et al. (2021)	Journal of Professional Nursing	Q1
China	Bi et al. (2019)	Medical Teacher	Q1
Taiwan	Lu et al. (2021)	International Journal of Technology and Design Education	Q1
USA	Cevik & Andre (2013)	International Journal of Educational Research	Q1
USA	Bagdasarov et al. (2012)	Journal of Empirical Research on Human Research Ethics	Q1
Italy	Berjano et al. (2017)	European Spine Journal	Q1
California	Demetri et al. (2021)	Journal of Surgical Education	Q1
Sweden	Groot-Jensen et al. (2016)	European Journal of Preventive Cardiology	Q1
China	Pan et al. (2020)	BMC medical education	Q1
Austria	Chéron et al. (2016)	BMC medical education	Q1
Indonesia	Saija et al. (2022)	Jurnal Pendidikan IPA Indonesia	Q2
Turkey	Cetin (2021)	Journal of Chemical Education	Q2
China	Chan et al. (2016)	Journal of Nursing Research	Q2
Turkey	Çiğdemoğlu & Geban (2015)	Chemistry Education Research and Practice	Q2
South Africa	Veale et al. (2018)	Chemistry Education Research and Practice	Q2
Belgium	Baeten et al. (2012)	Educational Studies	Q2
Germany	Gaupp et al. (2016)	BMC Medical Education	Q2
Kalamazoo	Bauler et al. (2018)	Journal of microbiology & biology education	Q2
China	Du et al. (2013)	European Journal of Dental Education	Q2
Chicago	Chowaniec et al. (2018)	European Journal of Dental Education	Q2
Florida	Behar-Horenstein et al. (2015)	Journal of dental education	Q2
Germany	Zumbach et al. (2020)	Journal of Problem-Based Learning	Q2
India	Gade & Chari (2013)	American Journal of Physiology- Advances in Physiology Education	Q2
Saudi Arabia	Alhazmi & Quadri (2020)	Journal of Dental Education	Q2
Netherlands	Vogelzang et al. (2020)	Chemistry Education Research and Practice	Q2
Los Angeles	Blazer et al. (2012)	Journal of Cancer Education	Q2
USA	Fortun et al. (2017)	Journal of Biological Education	Q2
Australia	Malau-Aduli et al. (2013)	BMC Medical Education	Q2
United States	Williams (2019)	Journal of Chemical Education	Q2
South Korea	Yoo & Park (2015)	Nursing and Health Sciences	Q2
Turkey	Günter et al. (2019)	Education Sciences	Q2
Australia	Nicklen et al. (2016)	Education for Health: Change in Learning and Practice	Q3
Finland	Matilainen et al. (2021)	Chemistry Teacher International	Q3
Saudi Arabia	Alsunni & Rafique (2021)	Journal of Taibah University Medical Sciences	Q3

Saudi Arabia	Majeed (2014)	Journal of Taibah University Medical Sciences	Q3
Philippines	Magwilang (2022)	International Journal of Learning, Teaching and Educational Research	Q3
Spanish	García-Ponce et al. (2021)	Biochemistry and Molecular Biology Education	Q4
India	Nair et al. (2013)	Journal of Clinical and Diagnostic Research	Q4
Portland	Major et al. (2021)	Journal of Chiropractic Education	Q4
Florida	Thibaut & Schroeder (2020)	Biochemistry and Molecular Biology Education	Q4
Taiwan	Tsao et al., (2022)	International Journal of Radiation Oncology, Biology, Physics	Q4

Note. Articles selected based on mapping results.

The study is mostly found in the journal Scopus Q1 (n = 21), followed by Scopus Q2 (n = 21), Scopus Q3 (n = 5), and Scopus Q4 (n = 5). The national contexts of reviewed studies were mostly from China, followed by Turkey, USA, Australia, Korea, India, Austria, Belgium, US, and the rest from Florida, the Netherlands, UK, Spain, Iran, Spanish, Germany, Italy, Sweden, Indonesia, Finland, South Africa, and Taiwan.

Coding Process: Phase 1

This review involved a repetitive two-phase coding process. Phase 1 collected descriptive information about each article, as expected in a systematic review. All abstracts and studies were read to identify the report's identity, the research's problem and purpose, research methods, and findings.

Coding Process: Phase 2

In stage 2 of the coding process, including the identity of the article, research objectives, research methods used, and research findings. Initial coding was cyclical, iterative, and inductive, examining the different levels of analysis, definition, and operationalization found in the study. Based on these findings, we refined the code for checking the validity of qualitative data by triangulation data using inter-rater reliability (Birt et al., 2016; Carter et al., 2014). Here is a description of empirical studies included in the review of the 52 articles:

Description of the Problem and Research Objectives

We encoded the description of the problem and the purpose of the research according to the categories suggested by Birt et al. (2016). Based on the results of the study, it shows that of the 51 articles reviewed, there are studies on Case-Based Learning Inquiry (n = 18), Case-Based Learning-Problem Based Learning (n = 13), Case-Based Learning-Project Based Learning (n = 12), Case-Based Blended (n= 4), Case-Based Online (n =3) and Case-Based Collaborative (n= 2).

Article Identity

Most of the articles (n = 23) were published between 2012 and 2016, and continuous publications from 2017 to 2022 were 29 articles. The trend of research related to the case-based approach has increased in recent years.

Research Methods

The articles reviewed in this study focused on articles that applied experimental methods in science education. By comparing the application of CBL-I, CBL-PBL, CBL-PjBL, Case-Based Blended, Case-Based Online and Case-Based Collaboration to understand a particular concept, it was interesting to evaluate whether these types of Case-Based were used to convey the same conceptual information on a specific topic or whether they were focused on different variables and phenomena. In this review, 52 articles studied the type of case-based for the same problem, sometimes carried out identically, sometimes slightly different in the variables tested, but still referred to the same learning topic. This made the studies and results more comparable. The focus is not on standard methods for combining different CBL perspectives but on studying science topics with these different CBL approaches.

Findings

Implementation of the CBL Approach in Science Education

The following characteristics of each CBL based on syntax are described in Table 2.

Table 2

The Syntax of CBL in Science Education

CBL type	CBL syntax	Reviewed studies	Difficulties in CBL types
IBL	1) Formulating Problem Students are given a problem to find the answer to. 2) CollectingData Students are asked to look for supporting data as a process of proving hypotheses through experimental methods. 3) Drawing Conclusions & Interpretation of data Students are asked to conclude and interpret experimental data through presentations.	Çam & Geban (2017); Günter et al. (2019); Günter &Alpat (2019); Lu et al. (2021); Magwilang (2022); Yalçınkaya et al. (2012); Vogelzang et al. (2020); Williams (2019); Zumbach et al. (2020); Cevik& Andre (2013); Saija et al. (2022); García-Ponce et al. (2021); Fortun et al. (2017); Baeten et al. (2013); Aylin & Geban (2013; Cetin (2021); Chéron et al. (2016); Çiğdemoğlu & Geban (2015); Matilainen et al. (2021); Sarioglan & Can (2021).	• The search and collection of information take a long time. • The collect irrelevant and insignificant information. • Processing information to formulate problem solving and conclusions is still difficult
PjBL	1) Preparing project questions or assignments Questions should be able to encourage learners to perform an activity or project. 2) Designing or planning for the project Planning contains supporting activities to be carried out, tools, and materials that are useful for completing the project. 3) setting a schedule for the implementation of project	Hempel et al. (2016); Hong & Yu (2017); Nair et al. (2013); Malau-Aduli et al. (2013); Major et al. (2021); Majeed (2014); Pan et al. (2020); Yoo& Park (2015); Yoo & Park (2014); Chan et al. (2016); Burgess et al. (2021).	• Solving the problem is so complex that it takes a long time. • Students have difficulty in conducting experiments and data collection due to the large amount of equipment that must be provided. • Students have difficulty in understanding the topic as a whole.

	completion Activities at this stage include: (a) creating a timeline, (b) determining the final project completion target (deadline); (c) planning new ways of solving; (d) making an explanation of the reason for choosing a new way. 4) Monitoring project activities and developments Teachers act as monitors of student activities during project completion. 5) Testing results Testing results can be done through presentations or project presentations. 6) Evaluating activities or experiences Reflection on the activities and results of projects that have been carried out.		
PBL	1) Student orientation to the problem. 2) Organize students to study and discuss. 3) Guide individual and group investigations. 4) Analyze and evaluate the troubleshooting process. 5) Develop and present the work.	Alhazmi & Quadri (2020); Alsunni & Rafique (2021); Bi et al. (2019); Behar-Horenstein et al. (2015); Demetri et al. (2021); Du et al. (2013); Gholami et al. (2021); Groot-Jensen et al. (2016).	• Students have difficulty in solving problems because there are no instructions for solving their problems. • In problem-solving activities take a long time.
Blended & Online	1) Online: • Problem orientation. • Organizing online discussion forums. 2) Face to face: • Guide scientific research. • Analyze and evaluate the problem-solving process. • Summarize and interpret the work.	Gaupp et al. (2016); Raurell-Torredà et al. (2015); Blazer et al. (2012); Ha (2020); Nicklen et al. (2016).	• It is challenging to implement if the facilities and infrastructure do not support it. • Internet access that is not smooth can hinder the learning process.
Collaborative	1) Delivering goals and motivating students. 2) Presenting information in the form of demonstrations or through reading materials. 3) Organizing students into	Veale et al. (2018); Chowaniec et al. (2018); Krupat et al. (2016); Thibaut & Schroeder (2020).	• Takes a long time. • Difficulty in finding friends who can work together.

	study groups. 4) Guiding group work and study. 5) Assessing what has been learned so that each group presents their work. 6) Giving awards both as a group and individually.	

Note. Analysis of the difficulties of the syntax of CBL types.

Table 2 shows that three types of CBL are widely applied in science education, including inquiry-based learning (IBL), project-based learning (PjBL), and problem-based learning (PBL) and the rest being CBL-Blended, CBL-Oline, and CBL-Collaborative.
Based on Table 2, it can be analysed the strength of the types of CBL in science education:

a) Case-Based Learning-Inquiry (CBL-Inquiry)

CBL-Inquiry prioritises the learning process through scientific experience in finding information, asking questions, and investigating environmental phenomena to find a concept or principle. The strength of the inquiry-based CBL approach is to emphasise the development of the cognitive aspect (Naping & Musywirah, 2019), affective aspect (Çam & Geban, 2017; Baeten et al., 2013; Aylin & Geban, 2013; Cetin, 2021; Chéron et al., 2016), psychomotor aspects to create more meaningful learning (Baeten etal., 2013; Magwilang, 2022; Yalçınkaya et al., 2012), and provide space for students to learn by their respective learning styles (Vogelzang et al. 2020; Zumbach et al. 2020; Fortun et al. 2017) and can improve the student learning experience (Cevik & Andre, 2013; Saija et al. 2022; Williams, 2019; Sarioglan & Chan, 2021;Çiğdemoğlu & Geban, 2015; Matilainen et al., 2021).

b) Case-Based Learning – Project-Based Learning (CBL-PjBL)

CBL-PjBL is a project learning strategy that emphasizes solving problems that occur in everyday life. Using problems in project-based learning is the first step in gathering and integrating new knowledge (Miller et al., 2021). The strength of the CBL-PjBL is that it trains students to use reasoning in overcoming problems (Major et al., 2021; Majeed, 2014; Pan et al., 2020), to make hypotheses in problem-solving (Yoo & Park, 2015), to think critically and contextually with real problems faced (Yoo & Park, 2014), to conduct trials in proving hypotheses (Hong & Yu, 2017; Chan et al., 2016), and to make a decision about problem-solving (materials) during the study of problems and alternative problem solving (Nair et al., 2013; Malau-Aduli et al., 2013; Burgess et al., 2021; Hempel et al., 2016).

c) Case-Based Learning-Problem Based Learning (CBL-PBL)

CBL-PBL is a learning strategy that involves students solving a problem through the stages of the scientific method so that students can learn knowledge related to environmental issues while having the skills to solve problems. The strength of the CBL-PBL approach is that it challenges students to discover new knowledge (Alhazmi & Quadri, 2020; Alsunni & Rafique, 2021; Bi et al., 2019), helps students transfer learning to understand real-life situations (Behar-Horenstein et al., 2015; Demetri et al., 2021), and develops students' ability to think critically (Du et al., 2013; Gholami et al., 2021; Groot-Jensen et al., 2016).

d) Case-Based Learning-Blended (CBL-Blended)

Case-based blended is a learning strategy that involves online meetings via website and offline through face-to-face meetings. Some of the strengths of CBL-Blended from research results are:

students have easier access to learning materials (Gaupp et al., 2016; Raurell-Torredà et al., 2015; Blazer et al., 2012), free to study online materials (Ha, 2020; Nicklen et al., 2016), can accelerate transfer from declarative to procedural knowledge in practice (Turk et al., 2019), affect significantly on knowledge and attitudes changes and student's moral reasoning (Karamzadeh et al., 2021), and also on innovative knowledge, problem-solving abilities, and student learning satisfaction (Kang & Kim, 2021; Duckwitz et al., 2022). The learning strategy is also effective in improving clinical teaching competence, self-efficacy, attitudes towards web-based learning, and blended learning outcomes (Wu et al., 2020).

e) Case-Based Learning-Online

CBL-Online is fully online learning. Some of the strengths of CBL-Online from research results are: it provides great opportunities in online learning activities which supports competency-based education, problem-based learning and case-based learning (Sistermans, 2020), it makes the students easier to determine the purpose of their participation in discussions, and can adopt various strategies to meet the objectives of participation in a discussion (Koehler et al., 2020). It also helps lecturers and students to conduct practicum simulations online during the Covid-19 pandemic (Thibaut & Schroeder, 2020). Moreover, it can integrate basic science and clinical science knowledge to improve student performance and perceptions (Major et al., 2021; Koehler, 2023).

f) Case-Based Learning-Collaborative (CBL-Collaborative)

Case-Based Learning-Collaborative is a CBL approach that emphasizes team work to achieve mutual success. The strength of CBL-Collaborative is that it can improve collaboration (Veale et al., 2018; Chowaniec et al., 2018) and social interaction skills (Krupat et al., 2016; Thibaut & Schroeder, 2020).

The reviewed studies show that CBL learning is dominantly relevant to inquiry-based learning, problem-based learning (PBL), and project-based learning. This means that CBL learning is an active learning approach closely related to Inquiry-Based Learning, Problem-Based Learning, and Project-Based Learning, which are incorporated into the same learning system, namely active learning. While the rest is applied in CBL-Blended, CBL-Online and CBL-Collaborative.

CBL in Science Education by Discipline

The review results show that the health sciences dominate in implementing the case-based approach in science education, as presented in Table 3.

Table 3

CBL Use by Discipline

Discipline	Frequency (%)	E.g., (author)
Chemistry	18 (35%)	Çam & Geban (2017); Günter et al. (2019); Günter & Alpat (2019); Lu et al. (2021); Magwilang (2022); Yalçınkaya et al. (2012); Vogelzang et al. (2020); Williams (2019); Zumbach et al. (2020); Cevik & Andre (2013); Saija et al. (2022); Aylin & Geban (2013; Cetin (2021); Çiğdemoğlu & Geban (2015); Matilainen et al. (2021); Sarioglan & Can (2021); Veale et al. (2018); Thibaut & Schroeder (2020).
Biology	3 (6%)	García-Ponce et al. (2021); Fortun et al. (2017); Baeten et al. (2013).
Physics	1 (1%)	Tsao et al. (2022).

Health	30 (58%)	Alhazmi & Quadri (2020); Alsunni & Rafique (2021); Bi et al. (2019); Blazer et al. (2012); Behar-Horenstein et al. (2015); Chowaniec et al. (2018); Demetri et al. (2021); Du et al. (2013); Gaupp et al. (2016); Gholami et al. (2021); Groot-Jensen et al. (2016); Ha (2020); Hempel et al. (2016); Krupat et al. (2016); Nair et al. (2013); Nicklen et al. (2016); Malau-Aduli et al. (2013); Major et al. (2021); Majeed (2014); Pan et al. (2020); Raurell-Torredà et al. (2015); Yoo& Park (2015); Yoo& Park (2014); Zhao et al. (2020); Gade& Chari (2013); Berjano et al. (2017); Bagdasarov et al. (2012); Chan et al. (2016); Chéron et al. (2016); Hong & Yu (2017).

Note. Percentage of CBL application in science learning.

This finding leads us to consider that the implementation of a case-based approach to the science learning and teaching focuses on the use of contexts related to everyday life that play a role in complementing and allowing the acquisition of the content of the disciplines that are the object of teaching.

Discussion

Implementation of the CBL Approach in Science Education

The study found that CBL was represented mostly in three learning approaches, namely CBL-IBL, CBL-PBL, CBL-PjBL, and the rest being CBL-Blended, CBL-Oline, and CBL-Collaborative. Most studies on the effect of CBL application including CBL-Inquiry show significant differences before and after learning on improving scientific attitudes and learning motivation, academic achievement, knowledge, understanding of concepts, quality of learning (Çam & Geban, 2017; Baeten et al., 2012); (Günter et al., 2019; Günter & Alpat, 2019); (García-Ponce et al., 2021); (Nair et al., 2013); (Baeten et al., 2013). CBL-PjBL effectively improves team performance skills, communication skills, problem-solving skills, and laboratory skills, interaction, communication skills, clinical thinking skills, self-study skills, group performance, experiential learning, improving better concept experience, critical thinking skills, communication skills, problem-solving skills and learning motivation, laboratory skills (Ha, 2020); (Zhao et al., 2020); (Hempel et al., 2016; Krupat et al., 2016), (Nicklen et al., 2016); (Gaupp et al., 2016; Yalçınkaya et al., 2012); (Hong & Yu, 2017); (Yoo & Park, 2015; Yoo & Park, 2014); (Raurell-Torredà et al., 2015; Williams, 2019). CBL-PBL effectively improves basic knowledge retention, problem-solving ability, student satisfaction level, independent learning, clinical reasoning ability, and satisfaction in learning, ethical sensitivity, learning achievement, ability to receive feedback and learning motivation, understanding of green chemistry principles, conceptual understanding, interaction (Malau-Aduli et al., 2013); (Gholami et al., 2021); (Bi et al., 2019 & Dewi et al., 2022); (Chan et al., 2016; Kulak & Newton, 2014); (Tammeleht et al., 2019; Yang et al., 2019); (Thibaut & Schroeder, 2020; Kantar & Massouh, 2015); (Lei et al., 2016; Salam et al., 2018; Morozs et al., 2016); (Bianchi et al., 2015); (Ballard & Mooring, 2021); (Papatraianou, 2016); (Tan et al., 2014).

A small number of other studies on Case-Based Blended and Case-Based Collaborative showed that there was an increase in problem-solving skills (Koehler et al., 2020; Medina et al., 2013), understanding of basic concepts (Burgess et al., 2021; Smits et al., 2012; Harman et al., 2015), experience (He et al., 2013; Nicklen et al., 2016), performance (Turk et al., 2019), interaction (Carrasco et al., 2018).

CBL in Science Education by Discipline

Case-Based Learning applications in science education were dominated by health (58%), chemistry (35%), physics (1%) and biology (6%). This suggests that CBL is more context-oriented in everyday life. Context becomes increasingly essential in science learning because it can be used as a tool to (a) make science learning more relevant to students' lives; (b) address student learning outcomes; (c) increase the argument for dialogue; (d) improve the ability to evaluate scientific information; and (e) include essential aspects of science literacy (Sadler & Zeidler, 2004). Using context in learning is expected to be aware of essential aspects in the creation of science, such as uncertainty, tentativeness, subjectivity, multiple perspectives, the role of funding, political interests, and the attachment of science to the social (social embeddedness of science) (Rahayu, 2021; Mustafaoglu & Yücel, 2022). Examples of contexts used in science learning include climate change or global warming, pollution, nuclear power plants or additives to food, health (Rahayu, 2019). The stages in using the context in science learning can be: a) identifying the science topic to be taught and the learning context in the form of popular issues related to the topic. The context raised can be obtained through popular mass media and recognized credibility; b) analysing the depth and breadth of topic related to the context to match the student's level of knowledge; c) compiling learning scenarios and student activity sheets by selecting questions that can train students to think critically and other skills needed in scientific literacy (Rostikawati & Permanasari, 2016; Yilmaz et al., 2022). Thus, it can be concluded that using context in science education will better visualize abstract concepts to be more concrete. CBL tends to focus on concrete, specific occasions—cases or problems— as a context for learning where the target knowledge is relevant. Contextualizing the learning contributes to both student motivation and meaning creation. The cases and problems are not merely supplemental illustrations but function centrally as the occasion for learning since cases situate the science content knowledge in real-world contexts (Allchin, 2013).

Context is a starting point for developing scientific thinking (Fritz, 2019). Since the context aims to present scientific concepts to students through activities in their chosen daily life, it can increase their motivation so that they are interested in learning science (Almeida et al., 2023; Bahtaji, 2023). Students should shape contexts, whether physically, conceptually, or related to the awareness of values, which can lead them to engage in learning to gain understanding, reflect, and create meaningfulness in their knowledge (Wagner et al., 2023). The activity of creating meaningful learning will be possible if the learning process does not have a separation between what is learned and the environment in which the problems studied can be found (Chi et al., 2023). This is where the position of the context becomes critical as a source or situation in which the phenomena and or problems of science can be found, studied, and interpreted in the practice of teaching and learning (King & Ritchie, 2012). Context also plays a role in increasing the intensity of student participation through activities of meaningful science knowledge by involving awareness of social values (Osborne et al., 2012). The position and role of the social dimension in science learning and teaching can be reflected in the issues that have been implemented in various studies so far. Issues such as vaccination, genetically modified organisms (GMOs), nuclear energy or mobile phones, their impact on health, and several environmental-related problems have been widely developed and implemented (Subiantoro, 2017).

Difficulties Found During the Implementation of the CBL Approach in Science Education

Although CBL has been widely researched by researchers, the reality shows that there are still difficulties faced by lecturers and students during the implementation of CBL ıncluding CBL-Inquiry are a) it makes it hard for students to plan to learn because it goes against their learning habits; b) it takes a long time, so lecturers often find it hard to fit it into the set amount of time; c) it is hard to put into place if the criteria for learning success are based on how well the students learn the subject. CBL-Problem-Based Learning are a) if students do not have confidence that the problem being studied is challenging to solve, then students will feel reluctant to try; b) it needs to be supported by books that can be used as understanding in learning activities; c) takes a long time; d) not all learning materials can be applied using this model. CBL-Project-Based Learning is that it requires much time in the learning process; lecturers must constantly monitor every student activity, so lecturers activities must be extra hard work to supervise every student activity, and students have difficulty solving very complex problems.

Based on the difficulties found in CBL implementation, we consider that the given cases should be based on the context of science facts and problems to students in order to create relevance between the science knowledge they learn and the problems of everyday life (ColucciGray & Fraser, 2012). Illustration of the context presented in the form of a case to make it easier for students to find and collect relevant information. Students are asked to review and analyse various information obtained independently to make it easier to process information in formulating problem-solving plans and help lead to more specific problem solving so that less time is needed and more efficient. In addition, providing solutions for us that students must be directed to be able to design experimental procedures independently as instructions in solving problems so that it can make it easier for students to carry out scientific investigations, data collection, and a thorough understanding of concepts which ultimately takes less time and more efficient.

Thus, optimising each learning stage is necessary to overcome the difficulties found. In optimizing CBL learning settings, it is important to analyse the need to direct the learning process to be more effective and efficient in science learning.

Conclusion

Based on the analysis of the review literature from 2012 to 2022 on case-based learning in science education. It was found that the CBL learning approach is implemented in three learning approaches, namely CBL in Inquiry-Based Learning, CBL in Problem Based Learning, and CBL in Project-Based Learning, which is incorporated in the same learning system, namely active learning. While the rest is applied in CBL-Blended, CBL-Online and CBL-Collaborative; the application of a case-based approach in science education is dominated by health (58%), followed by chemistry (35%), physics (1%) and biology (6%). Difficulties found during the implementation of the CBL approach in science education are processing information to formulate problem-solving, conducting experiments, data collection, and drawing conclusions so that the time needed is long too long. This literature review implies that the CBL approach can be applied in narrower cases like problem-based learning and more open cases identical to project-based learning and can be applied in the case of content equal to inquiry-based learning. The recommendation for further researchers is to optimise the application of a case-based approach in science education. It is necessary to design a new strategy that involves real-life contextual cases to accommodate the weaknesses found during the CBL approach in learning and teaching science.

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