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Review Article

A systematic review into the approach of contextual teaching and learning in mathematics education

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ABSTRACT

Mathematical literacy, encompassing the ability to think analytically and apply mathematical concepts to solve problems in authentic contexts, is a key competence of the 21st century, which is also emphasized in the new curricular framework in Slovakia. One of the didactic approaches that support the development of mathematical literacy is contextual teaching and learning (CTL). Existing literature reports a range of methods for implementing the CTL approach, indicating considerable variability in its conceptualization and application across studies. The aim of this study is to provide a systematic perspective of the research focused on the implementation of CTL in mathematics education. Relevant studies were retrieved from the Web of Science, Scopus, ERIC, and Google Scholar databases. The review included studies that examined CTL-based instruction in mathematics education and were published between 2015-2024. The methodological framework of this review was guided by the principles outlined by Mareš (2013) employing PRISMA 2020 checklist for reporting. The findings indicate the existence of three distinct levels of CTL implementation that differ in their degree of alignment with CTL as defined in the literature. Specifically, three levels of CTL incorporation into the educational process were identified: (1) direct implementation of the REACT strategy, in which CTL is applied through all its components in accordance with the original sequential model; (2) application of CTL components as defined by Johnson (2002) and Hamruni (2012); and (3) use of alternative instructional strategies, in which only selected CTL elements are implemented.

Keywords: contextual teaching and learning, mathematics, primary education, real context

INTRODUCTION

Developing domain-specific literacies alongside cross-curricular literacies, which foster a more integrated connection between knowledge and competencies, occupies a key position in the new primary curriculum of the Slovak Republic (Ministry of Education, Research, Development and Youth of the Slovak Republic, 2023). The recent curricular reform also redefines the roles of both learners and teachers. Learners are perceived as active participants in their own learning trajectories, while the teacher's role is reconceptualized as that of a guide and facilitator. Slovak education thus aims to systematically develop learners' ability to understand and apply educational concepts in context.

Learning invariably takes place within a particular context (Brown et al., 1989). However, real-world context should not be understood as an instructional add-on; it constitutes an integral component of learning, as concepts and strategies develop through participation in communities of practice (Lipták, 2025). As noted by Abu-Rasheed et al. (2023), several learning theories emphasize the importance of context in the learning process, including situated learning theory, inquiry-based learning, project-based learning, and constructivist theory.

One constructivist-oriented educational approach that explicitly emphasizes the transfer and application of knowledge across educational and real-world contexts is contextual teaching and learning (CTL). Real-world context represents a central philosophical principle of the CTL approach and, within mathematics education, of the realistic mathematics education (RME) approach (Lipták, 2025). A study by Putri et al. (2022), which examined the effects of implementing RME and CTL on the development of students' mathematical communication skills, reported no statistically significant differences between the two approaches. The authors therefore suggest that RME and CTL may function as alternative instructional approaches in educational practice.

However, considering the current reform requirements of the Slovak curriculum, the CTL approach appears to be more appropriate than RME, particularly due to differences in their didactic orientation. RME is primarily a mathematics-specific approach that primarily focuses on the process of mathematization (Gravemeijer, 1994) and is grounded in six core principles: activity, reality, level, intertwinement, interactivity, and guidance (Van den Heuvel-Panhuizen & Drijvers, 2014). In contrast, CTL is not limited to a single subject domain; it connects learning to real-life contexts and supports learners in making meaningful connections and effectively transferring their knowledge and skills to new situations (Afni & Hartono, 2020). Based on these considerations, and in alignment with the new curricular framework in Slovakia, this study adopts CTL as its theoretical and pedagogical framework.

The potential of the CTL approach to enhance mathematical literacy is realized through real-world application. Also, in international large-scale surveys such as TIMSS, the ability to apply acquired mathematical knowledge in real-life situations is regarded as essential. Moreover, the forthcoming TIMSS assessment in 2027 will place emphasis on authentic tasks designed to more accurately capture learners' deep conceptual understanding and the development of critical thinking skills (International Association for the Evaluation of Educational Achievement [IEA], 2024). Finally, CTL facilitates the alignment of mathematics education with the evolving demands of a technology-driven and interconnected society, thereby providing a practical framework for the implementation of Education 4.0 principles. The importance of linking mathematics to real-world contextual demands of modern society within Education 4.0 has been emphasized in a recent Delphi study by Taja-on et al. (2025).

To examine how CTL has been conceptualized and implemented in mathematics education, this study employs a systematic review methodology. The study addresses the following research questions (RQs):

1. **RQ1.** How was the CTL approach conceptualized and implemented in research studies?
2. **RQ2.** What specific CTL strategies have been identified as effective in teaching mathematics?
3. **RQ3.** What limitations and risks are associated with implementing CTL in mathematics instruction regarding the development of mathematical literacy?

A systematic review was chosen to synthesize existing knowledge, refine operational definitions of key concepts, and develop a comprehensive perspective of the investigated issue.

THEORETICAL FRAMEWORK

The CTL concept, grounded in the constructivist paradigm and solidified during the 1990s, posits that educational content should be connected to real-life contexts and that learning should occur within authentic situations in which knowledge acquisition is inseparable from the development of practical skills (Johnson, 2002). CTL is understood as a process that facilitates the acquisition of knowledge through linking new information to learners' prior experiences. Such connection between educational content and real-life contexts is intended to foster learners' intentional awareness of the relevance and meaningfulness of learning. Moreover, CTL promotes an integrated and multidisciplinary approach to teaching, enabling students to apply acquired knowledge and skills across diverse contexts. Its core idea is learning through activity, which in turn leads to the formation of meaningful cognitive connections (Berns & Erickson, 2001; Hull, 1995; Johnson, 2002).

However, the literature reveals discrepancies in how CTL is incorporated into the educational process. These inconsistencies underscore the relevance of the present study and directly inform the RQ1. The REACT strategy is regarded as a core framework of CTL (Crawford, 2001; Herlina & Ilmadi, 2022; Suryawati & Osman, 2018; Yildiz & Baltaci, 2016) introduced by Center for Occupational Research and Development (Hull, 1995). It encompasses five components: relating, experiencing, applying, cooperating, and transferring. They can be characterized as follows:

- Relating—learning grounded in learners' own life experiences or prior knowledge. This component is considered one of the most effective contextual teaching strategies and aligns closely with constructivist principles.
- Experiencing—learning by doing, through exploration, hands-on activities, discovery, and invention. This may also involve the use of manipulatives, problem-solving tasks, and laboratories.
- Applying—acquiring knowledge through its active use in practical situations.
- Cooperating—learning through collaboration, communication, and sharing of perspectives, this includes participation in group process, observation, suggestion, discussion, analysis, and reflection.
- Transferring—applying acquired knowledge in new or previously unfamiliar contexts.

The strategy is designed to follow the sequential order of these components (Crawford, 2001).

Building on the REACT framework, the RANGKA strategy (Suryawati & Osman, 2018; Suryawati et al., 2010), an acronym for: problem summary (rumuskan masalah), observed through activities (amati melalui kegiatan), state (nyatakan), merge (gabungkan), collaboration and communication (kerjasama dan komunikasi), and practice (amalkan), was developed as an alternative CTL strategy.

By contrast, other authors conceptualize CTL without explicitly referencing the REACT strategy, instead emphasizing a set of key components. For instance, Blanchard (2001) defines CTL through six core elements: reasoning, context, metacognition, real-life connections, peer learning, and authentic learning. Similarly, Johnson (2002) conceptualizes CTL as comprising eight elements including making meaningful connections, doing significant work, self-regulated learning, collaborating, critical and creative thinking, nurturing the individual, reaching high standards, using authentic assessment. Building on these findings with the aim of incorporating CTL into mathematics education process, we conducted a systematic comparison of existing research to establish operational definitions of CTL incorporation.

METHODOLOGY

This study employed a systematic review methodology in accordance with PRISMA 2020 checklist for reporting (Page et al., 2021). The systematic review was conducted to identify ways of incorporating CTL approach into mathematics education. A systematic review synthesizes existing research on a specific topic by identifying trends, research gaps, and recurring patterns in the published literature. It therefore provides a comprehensive overview and enables a deeper understanding of the issue under investigation (Brignardello-Petersen et al., 2024). To ensure methodological consistency, systematicity, and replicability, the review study followed a development diagram proposed by Mareš (2013).

Information sources for this review were retrieved from the Web of Science (WoS), Scopus, ERIC, and Google Scholar databases. These databases were selected due to their relevance to education and social science research and their broad coverage of peer-reviewed literature in mathematics education. The selection of available databases was limited by institutional access privileges. Studies published between 2015 and 2024 were included in the analysis, and the search process was conducted in March 2025.

The objective of this review study was to identify and synthesize empirical evidence on ways of incorporating the CTL approach into mathematics education. Core search terms focused on the CTL approach and mathematics education. Keywords included combinations of: "contextual teaching and learning" OR "contextual learning" OR "context-based learning" AND "mathematics education" OR "mathematics teaching" OR "mathematics learning".

Table 1. Criteria of inclusion and exclusion

Criteria	Inclusion	Exclusion
Article title and content	Relevant title and fulfilled the requirement of the study	The title is irrelevant and fails to align with the study's objectives
Publication year	Publications from 2015 to 2024	Publications other than the identified range
Publication type	Journal article	Reviews, editorials, and non-empirical studies
Language	English	Others
Field of article study	Math and education	Others than math and education
Accessibility	Open access only	Preview articles and requires payment or subscription

The search process was further limited by several eligibility criteria. Thematically, the selection of studies was restricted to the fields of mathematics and education. Only peer-reviewed journal articles published in English with full-text access were included to minimize the risk of misinterpretation and mistranslation (Hidayat et al., 2025). The final criterion was the publication time frame, which was set to the period 2015-2024. This ten-year span was chosen to capture recent developments and reflect the current state of research on the application of CTL in mathematics education. These restrictions were applied consistently across all databases to ensure uniform search parameters and to enhance the accuracy of identifying relevant studies.

Exclusion criteria included review articles, editorials, conference papers, non-empirical studies, publications outside the specified date range, studies not related to mathematics or education, and articles published in languages other than English (see **Table 1**).

In the second step, studies were screened based on an analysis of their titles and abstracts. Following PRISMA guidelines, two reviewers independently screened the titles and abstracts of all retrieved records against the predefined eligibility criteria. During the phase of qualitative assessment of the selected studies, the reviewers examined the extent to which each study was conceptually grounded in the constructivist paradigm. In parallel, the intervention strategies employed within overall research design in the selected studies were analyzed in relation to contextual interpretation and knowledge construction.

The adopted approach enabled reviewers to develop a deeper understanding of both philosophical positioning and practical execution of CTL teaching strategies in the included studies and supported a more nuanced qualitative synthesize. Any disagreements regarding qualitative appraisal were resolved through disconceptualizeussion until consensus was achieved. Although several of the identified records contained the selected keywords, many did not address them within the context of the CTL educational approach, which resulted in a substantial number of exclusions. Following title and abstract screening, the remaining 37 articles retrieved from the following databases: WoS (n = 1), Scopus (n = 6), ERIC (n = 15), and Google Scholar (n = 15) were eligible for full-text review.

After full-text assessment, additional studies were excluded due to duplication or thematic irrelevance to either the CTL approach or mathematics education. Ultimately, 16 studies met all inclusion criteria and were included in the final synthesize. A detailed overview of the study selection process, including numbers of records identified, screened, excluded, and included is presented in **Figure 1**.

The studies that met the inclusion criteria and were incorporated into the review are listed in **Table 2**. For a concise overview, **Table 2** includes author and year, title of the article, research sample, type of research (qualitative, abbreviated as QUAL, and quantitative as QUANT), and research methods and tools employed. The studies were subsequently analyzed according to the aspects outlined above. **Table 2** is ordered based on source databases–Scopus (1-3), ERIC (4-11), and Google Scholar (12-16).

Data were extracted from each included study using an extraction form capturing publication details, research design, educational context, mathematical content area, and reported strategies for implementing the CTL approach. The review also identifies gaps in the literature and highlights directions for future research. Due to heterogeneity in study designs and outcomes, a narrative synthesize was employed to identify recurring themes, patterns, and instructional strategies related to CTL implementation in mathematics education.

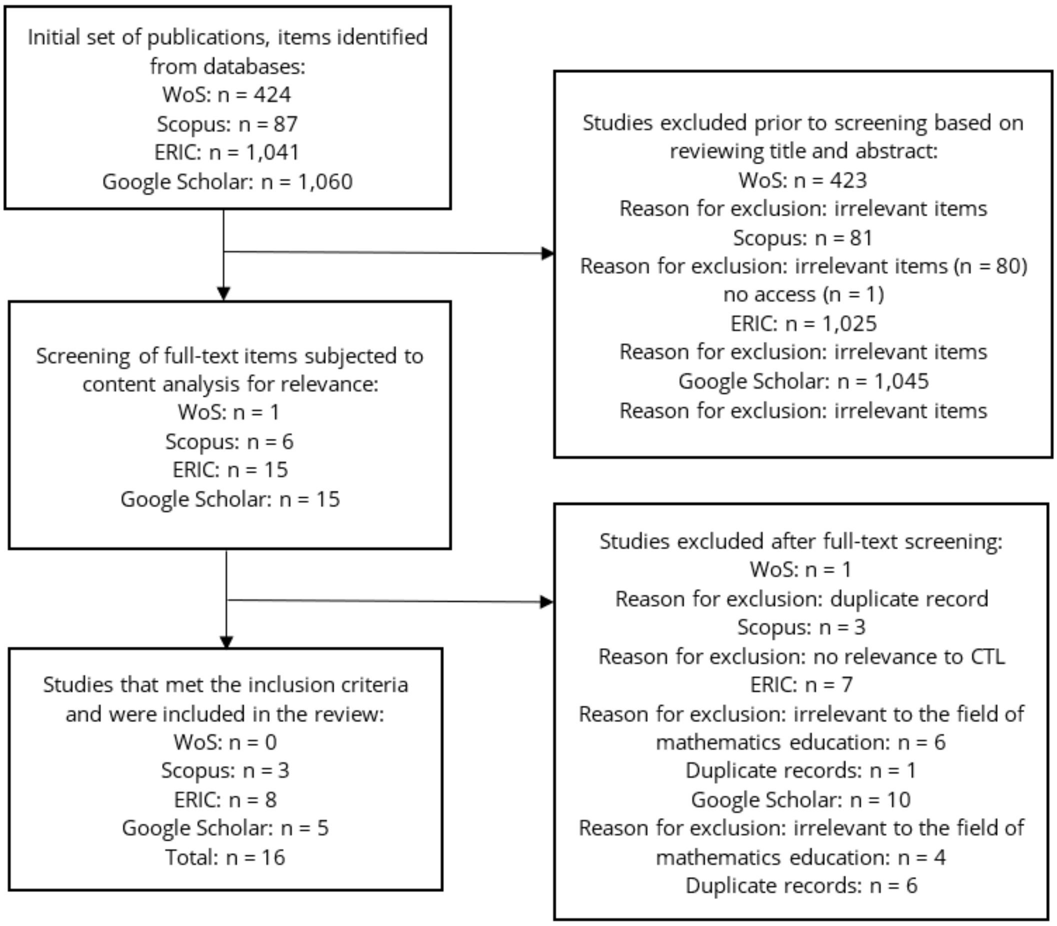

Figure 1. Flow diagram of the systematic selection process of relevant studies (Source: The authors' own work)

FINDINGS

This section presents the findings derived from the synthesis and analysis of the data. As illustrated in **Figure 1**, 16 articles were included in the systematic review. The analysis of the selected publications was guided by three RQs. In addition to **RQ1**, which examined how the CTL approach was conceptualized and implemented in research studies, the analysis focused on how CTL was incorporated into instructional practices. More detailed examples are provided from studies that addressed specific mathematical curricula. Five studies that focused on specific mathematical curricula were divided into three groups. The first group comprises two studies in the field of calculus, specifically differential equations.

Table 2. Summary of source studies on CTL in mathematics education

Reference	Title	Research sample	Type of research	Research methods and tools
Spooner (2024)	Using mathematical modelling to provide students with a contextual learning experience of differential equations	Tertiary education students of mathematics	QUAL case study	Observation, descriptive analysis
Kurniansyah et al. (2022)	Development of combined module using contextual scientific approach to enhance students' cognitive and affective	8th graders of basic school	QUANT development research	Questionnaire, interview, test
Kurniati et al. (2015)	Mathematical critical thinking ability through contextual teaching and learning approach	Primary education teacher trainees	QUANT experiment	Mathematical prior ability test, mathematical critical thinking ability test, observation, interview

Table 2 (Continued).

Reference	Title	Research sample	Type of research	Research methods and tools
Lestari et al. (2021)	The implementation of mathematics comic through contextual teaching and learning to improve critical thinking ability and character	4th grade pupils	QUANT quasi-experiment	Pre-/post-test, critical thinking questionnaire, character traits questionnaire
Khotimah and Masduki (2016)	Improving teaching quality and problem solving ability through contextual teaching and learning in differential equations: A lesson study approach	Teachers, tertiary education students of mathematics	Mixed methods action research	Observation, field notes, interview, descriptive analysis
Yildiz and Baltaci (2016)	Reflections from the analytic geometry courses based on contextual teaching and learning through GeoGebra software	Tertiary education students of mathematics	QUAL case study	Worksheets, semi-structured interview, models formed via GeoGebra software
Surya et al. (2017)	Improving mathematical problem-solving ability and self-confidence of high school students through contextual learning model	8th grade students	QUANT quasi-experiment	Mathematical problem-solving ability test, self-confidence scale
Ahdhianto et al. (2020)	The effect of metacognitive-based contextual learning model on fifth-grade students' problem-solving and mathematical communication skills	5th grade students	QUANT quasi-experiment	Problem-solving skills test, math, communication skills test
Priyadi et al. (2021)	The effect of contextual teaching and learning (CTL) model with outdoor approach towards the students' ability of mathematical representation	Secondary school students	QUANT quasi-experiment	Pre-/post-test, mathematical representation ability test
Pangemanan (2020)	Application of contextual teaching and learning approach on statistics material against student results	9th grade students	QUANT quasi-experiment	Pre-/post-test of mathematical abilities
Ekowati et al. (2015)	The application of contextual approach in learning mathematics to improve students motivation at SMPN 1 Kupang	7th grade students	Mixed methods action research	Observation sheet for students and teachers
Selvianiresa and Prabawanto (2017)	Contextual teaching and learning approach of mathematics in primary schools	4th grade pupils	QUANT quasi-experiment	Observation, pre-/post-test of mathematical ability test
Syamsuddi and Istiyono (2018)	The effectiveness of mathematics learning through contextual teaching and learning approach in Junior high school	8th grade students	QUANT pre-experimental case study design	Mathematical abilities test, observation, questionnaire
Yeni et al. (2019)	The effect of contextual teaching and learning approach and motivation of learning on the ability of understanding the mathematics concepts of grade V student	5th grade students	QUANT quasi-experiment	Post-test only factorial control group 2 × 2, mathematical knowledge and motivation to learning test
Mahendra (2016)	Contextual learning approach and performance assessment in mathematics learning	Secondary school students	QUANT quasi-experiment	Multiple choice numerical aptitude test, essay test
Nurlinda et al. (2024)	Students' mathematical reasoning ability and self-efficacy viewed from the application of problem based learning and contextual teaching and learning models assisted	Tertiary education students of mathematics	QUANT quasi-experiment	Initial mathematical ability test, mathematical reasoning ability test, self-efficacy questionnaire

The second group focuses on statistics, and the third group includes two studies concerned with geometry. In the first group, both studies on differential equations (Khotimah & Masduki, 2016; Spooner, 2024) were grounded in the concept of mathematical modelling and involved participants drawn from the same population, namely teacher trainees in the field of mathematics education. Spooner (2024) implemented a

CTL-based approach in the design and pilot testing of three educational units on differential equations. Within this mathematical modelling framework, students engaged with open-ended or ill-defined problems situated in real-life contexts. Across these studies, instructional tasks included

(1) ill-defined/open-ended modelling problems,

(2) cases that addressed the applications of mathematical modelling in real-life situations, and

(3) fictional scenarios that simulated authentic situations in which students formulated solutions utilizing differential equations.

Khotimah and Masduki (2016) applied the Lesson Study method, which aims at improving the educational process through collaboration of teachers and mutual analysis of their instructional practices. The research targeted not only students but also teachers and was conducted over four cycles during which the Lesson Study method was implemented. During these cycles, students' ability to solve CTL-based tasks using differential equations was analyzed. The CTL concept was integrated into the teaching process based on the characteristics defined by Hamruni (2012). The seven CTL components defined by Hamruni (2012), namely a constructivist approach, inquiry-based learning through exploration and discovery, questioning and seeking answers, a learning community supported by communication with others, modelling, reflection, and authentic assessment are conceptually derived from Johnson's (2002) CTL framework and represent an adapted and operationalized version of Johnson's (2002) components, particularly within regional educational literature in Indonesia. The authors of the study also provided a specific example of a CTL-based task:

> "In a work meeting room, a cup of hot coffee will be cold as time goes by. During the meeting, the room temperature is 25 °C, while the coffee temperature available at each desk is 70 °C. After 15 minutes passes, the coffee temperature drops to 30 °C. If the speed of change temperature change equals with the temperature difference between coffee and room temperature, what is the coffee temperature after the meeting goes for 30 minutes?" (Khotimah & Masduki, 2016, p. 6).

The researchers employed group work, followed by sharing individual findings and argumentation. The results of both studies confirmed the positive impact CTL had on students' understanding of how to apply mathematical knowledge in real-life contexts. Spooner (2024) additionally refers to an increase in students' self-confidence and self-efficacy when solving mathematical problems.

In the second group, which focused on implementing the statistics curriculum for 9th grade students, Pangemanan (2020) applied CTL elements as defined by Johnson (2002). The core set of eight components was complemented by an additional component referred to as develop thought. Although the study does not provide specific examples of CTL-based mathematical tasks related to statistical concepts such as mean value, median, and mode, it reported the frequency with which particular CTL components were incorporated into the teaching unit, with an emphasis on asking questions, working in groups and peer learning.

The third group examined the teaching of geometry curriculum through the CTL approach. Lestari et al. (2021) evaluated the effectiveness of a math comic strip intended for 4th grade primary school pupils. The comics depict the daily life of a primary school pupil who faces challenges in learning mathematics. The characters in the comics are caricatured in the way that their body parts are rendered as two-dimensional geometric shapes–squares, rectangles, triangles, ellipses, and circles. To illustrate the instructional approach, the authors present a specific excerpt from the comic for 4th graders, in which pupils are introduced to the properties of rectangles and squares, and learn how to determine length and width:

> "… because the paper has two pairs of opposite sides parallel and four right angles." "That's right. This paper is a rectangle." Then Izmi divided the rectangle into squares, as shown in the picture. "If the paper is divided into square units, can you measure the length and width of this rectangular paper?" (Lestari et al., 2021, p. 499).

Yildiz and Baltaci (2016) investigated how prospective mathematics teachers instruct cylindrical and spherical coordinate systems within the CTL framework utilizing GeoGebra software. The research was conducted as a case study involving eight mathematics teacher trainees and employed multiple datacollecting tools, including worksheets, semi-structured interviews, and GeoGebra-based models. The researchers adopted the REACT strategy, highlighting its benefits for student collaboration, mutual support, and effective handling of errors. Analysis of the interviews conducted with the participants of the study revealed that the teacher trainees perceived the teaching as meaningful and applicable to real-world settings.

Across analyzed mathematical studies, consistent pedagogical patterns emerge, including the use of authentic contexts, collaborative learning, inquiry-oriented tasks, and reflective discussion. These shared features suggest that CTL effectiveness may depend less on the specific mathematical domain itself than on how successfully real-life contextualization and CTL principles are integrated into instruction. However, the uneven distribution of studies across domains limits definitive conclusions.

Interpretation of Educational Effects

The findings provide empirical support for CTL as an effective instructional approach, demonstrating its capacity to strengthen learning outcomes, enhance learners' metacognitive development, and improve instructional quality. The two former aspects (learning outcomes and metacognition) were analyzed using Bloom's revised taxonomy of the knowledge dimension, which includes factual, conceptual, procedural, and metacognitive knowledge (Anderson & Krathwohl, 2001).

At the level of factual knowledge, several studies report improved retention and recall of mathematical knowledge following CTL implementation (Mahendra, 2016; Pangemanan, 2020; Selvianiresa & Prabawanto, 2017; Syamsuddin & Istiyono, 2018; Yildiz & Baltaci, 2016). These findings suggest that situating mathematical content within meaningful contexts enhances memory by increasing relevance and engagement.

Regarding conceptual knowledge, the reviewed literature indicates that CTL supports students' understanding and use of mathematical concepts. Ahdhianto et al. (2020) highlight enhanced ability to communicate using mathematical language, suggesting that CTL facilitates both comprehension and expression of mathematical ideas.

The most frequently reported effects of CTL were observed in the domain of procedural knowledge. Multiple studies have documented enhanced problem-solving abilities in mathematics following CTL implementation (Ahdhianto et al., 2020; Khotimah & Masduki, 2016; Kurniansyah et al., 2022; Nurlinda et al., 2024; Pangemanan, 2020; Surya et al., 2017). Additionally, several studies indicate that CTL facilitates students' ability to apply mathematical procedures in real-life contexts, thereby supporting meaningful learning (Ekowati et al., 2015; Selvianiresa & Prabawanto, 2017; Yeni et al., 2019).

Regarding metacognitive knowledge, several studies highlight the influence of CTL on students' learning-related self-regulation, including increased motivation, confidence, and persistence in mathematical problem-solving (Spooner, 2024; Surya et al., 2017). Moreover, positive effects were identified in terms of students' discipline, diligence, and reflective engagement with learning tasks, suggesting the development of metacognitive awareness and control over the learning process (Lestari et al., 2021).

Regarding the third aspect, the findings indicate a positive impact on the quality of instruction. The CTL implementation enhances instructional effectiveness by supporting more deliberate teacher preparation and more coherent learner (Khotimah & Masduki, 2016; Pangemanan, 2020).

Conceptualization and Implementation

The inconsistencies in CTL incorporation reported in the literature are also reflected in the diversity of approaches and methods described in the studies included in this review. Analysis of the selected studies reveals multiple strategies for implementing CTL in educational practice.

Based on the literature and findings of this review, the authors aim to consolidate existing knowledge regarding the incorporation of CTL into the educational process. The REACT strategy is identified as the dominant instructional strategy within the CTL approach. Despite this, the REACT strategy was explicitly applied in only one of the sixteen reviewed studies, namely Yildiz and Baltaci (2016). Nevertheless, several elements of the REACT strategy were implicitly implemented in other studies through various didactic procedures. Drawing on Crawford's (2001) definition, the extent to which the pedagogical approaches identified in the reviewed studies align with the REACT strategy can be systematically assessed based on their correspondence with its constituent components.

Table 3. Alignment of CTL components with the REACT strategy

Reference	Relating	Experiencing	Applying	Cooperating	Transferring	
Johnson (2002)	Making meaningful connections; using authentic assessment	Nurturing the individual		Collaborating; doing significant work	Critical and creative thinking	Self-regulation learning
Blanchard (2001)	Context, authentic learning; real-life connections		Reasoning	Peer learning		Metacognition

Table 4. CTL strategies in relation to the REACT strategy

	Relating	**E**xperiencing	**A**pplying	**C**ooperating	**T**ransferring
Other strategies	Contextual problems	Problem-solving, inquiry, graduated guided inquiry, open-ended modelling activity	Reasoning, questioning	Group/teamwork, exchanging opinion, sharing information, discussing	Integration subjects, solving the real problem outside the classroom

The CTL components articulated by Johnson (2002) and Blanchard (2001), as cited in Hudson & Whisler (2007), converge on several core characteristics, particularly their emphasis on connecting curricular content to authentic, real-life contexts and promoting collaborative learning. Both conceptualizations also highlight metacognitive development as a central element of contextual learning. Nevertheless, when assessed against the criteria of the comprehensive REACT strategy, these sets of CTL components appear to omit certain essential elements required for their complete and systematic implementation.

Accordingly, **Table 3** presents the extent to which individual components by Blanchard (2001), as cited in Hudson & Whisler (2007) and Johnson (2002) align with the REACT framework defined by Crawford (2001).

The systematic nature of the REACT strategy is grounded in the prescribed sequence of its five constituent instructional phases, which must be implemented in the order denoted by the acronym itself. This sequencing reflects an optimal instructional progression with each phase progressively facilitating learners' conceptual understanding, practical application, and knowledge transfer. Accordingly, the REACT strategy can be regarded as one of the most structured approaches to the implementation of CTL within the educational process (Crawford, 2001; Hull, 1995).

The review of empirical applications of CTL indicates that existing approaches vary in their alignment with the comprehensive conception of CTL. The primary assessment criterion employed in this review is the extent to which the instructional approaches fulfil the requirements of the REACT strategy as articulated by Crawford (2001).

The analysis of the studies included reveals three distinct levels of CTL incorporation into the educational process:

1. Direct implementation of the REACT strategy, in which CTL is applied comprehensively, adhering to the original sequential model and incorporating all of its fundamental components (e.g., Yildiz & Baltaci, 2016).
2. Application of CTL components as defined by Johnson (2002), and Hamruni (2012) which constitute a CTL framework but lack the explicit rigid structure and sequencing inherent to the REACT strategy (e.g., Khotimah & Masduki, 2016; Pangemanan, 2020; Selvianiresa & Prabawanto, 2017; Yeni et al., 2019).
3. Use of alternative instructional strategies, in which only selected CTL elements are utilized (Ahdhianto et al., 2020; Ekowati et al., 2015; Kurniansyah et al. , 2022; Kurniati et al., 2015; Lestari et al., 2021; Mahendra, 2016; Nurlinda et al. 2024; Priyadi & Yumiati, 2021; Spooner, 2024; Surya et al., 2017; Syamsuddin & Istiyono, 2018).

Although approaches classified at the third level do not explicitly adhere to the REACT framework, they remain compatible and can be mapped onto its components, as individual CTL strategies employed constitute implicit elements of the REACT strategy (see **Table 4**). Based on the foregoing analysis, three hierarchical levels of CTL incorporation into the educational process are delineated and are depicted schematically in **Figure 2**.

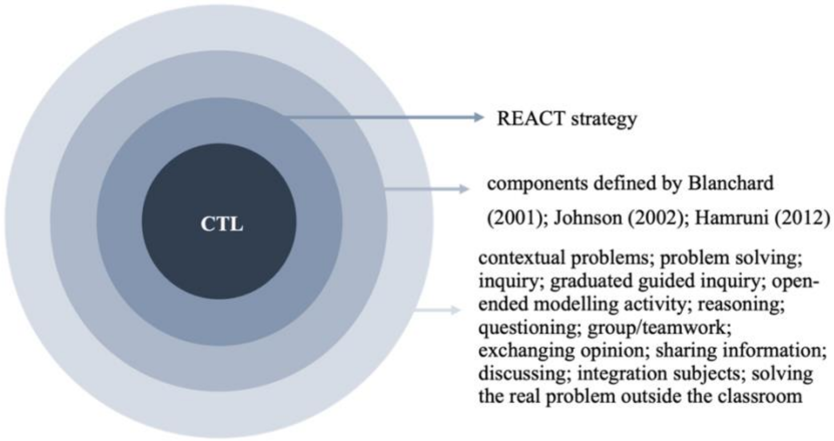

Figure 2. Hierarchical levels of CTL incorporation (Source: The authors' own work)

Possibilities for Further Research

Analyzing the recommendations in the reviewed studies, three main areas for further research were identified.

Focus on student

Kurniati et al. (2015) identified the effects of CTL on problem-solving, mathematical argumentation and communication as insufficiently explored. However, this issue has received more attention since 2015, specifically in the studies by Khotimah and Masduki (2016), Surya et al. (2017), Ahdhianto et al. (2020), Pangemanan (2020), Ahdhianto et al. (2020), Kurniansyah et al. (2022),and Nurlinda et al. (2024).

Focus on teacher

Kurniati et al. (2015) also raises the question of CTL effectiveness in developing problem-solving skills, mathematical reasoning and communication in teacher trainees. Ekowati et al. (2015) suggest examining teacher habits that may emerge under the influence of CTL. Specifically, they propose to examine the impact of this concept on creativity and teacher engagement. However, the studies conducted by Khotimah and Masduki (2016) and Pangemanan (2020) may provide answers to this proposition, as their findings indicate improvements in instructional preparedness of teachers.

Focus on instruction

Yildiz and Baltaci (2016) recommend GeoGebra software as an object for further research, particularly in developing contextual connections with analytic geometry concepts, which is consistent with the recommendations of Nurlinda et al. (2024).

Based on the limitations identified in the reviewed corpus, several areas for further research are proposed to address existing thematic and methodological gaps. In the studies conducted within the field of mathematics education, there was a prevailing tendency to examine cognitive development and effectiveness of CTL in comparison to traditional instruction. However, there is a notable scarcity of research focused on CTL effectiveness in relation to specific mathematical curriculum. Since only five of the reviewed studies addressed specific mathematical content, with two of them focused on the same content area–differential equations, future research should explore the application of CTL across diverse mathematical domains.

A predominant type of instructional lesson observed in the reviewed studies was a lesson focused on consolidation and repetition of previously learned material. However, application of CTL in a lesson introducing new content is under-researched.

Another significant finding concerns the preferred research sample. Among the analyzed studies, only two–Selvianiresa and Prabawanto (2017) and Lestari et al. (2021)–focused on pupils in primary education

Table 5. CTL strategies specifically effective in mathematics

CTL strategies that were specifically effective in mathematics	Reference	Educational effects	Bloom's revised taxonomy of the knowledge dimension
Discussion and question posing	Ahdhianto et al. (2020)	Promotes students' problem-solving	Procedural knowledge
		Promotes students' mathematical communication skills	Conceptual knowledge
	Lestari et al. (2021)	Positive effects in terms of students' discipline and diligence	Metacognitive knowledge
Beginning the process of learning mathematics by providing a contextual problem that relates to the mathematical concepts to be discussed	Ekowati et al. (2015)	Improvement in students' mastery of math concepts in class	Conceptual knowledge
	Khotimah and Masduki (2016)	Enhanced problem-solving abilities in mathematics	Procedural knowledge
Use of mathematics manipulatives as a form of visual aids in supporting abstract mathematical concepts	Ekowati et al. (2015)	Improvement in students' mastery of math concepts in class	Conceptual knowledge
Use of modelling activities, which provide a rich contextual learning environment for mathematics	Spooner (2024)	Enhanced understanding of the usefulness of mathematics and the diversity of its applications	Metacognitive knowledge
Creating a learning atmosphere with opportunities to express ideas and sharpen mathematical reasoning skills	Nurlinda et al. (2024)	Significant influence on students' mathematical reasoning abilities	Conceptual knowledge
Making conclusions and generalizations for similar problems or cases	Khotimah and Masduki (2016)	Enhanced problem-solving abilities in mathematics	Procedural knowledge
Teacher improvisation so that education is not dominated only by textbooks	Kurniansyah et al. (2022)	Enhanced problem-solving abilities in mathematics	Procedural knowledge

(grades 1- 4). This highlights the need for extending CTL research to primary education setting as it has been researched marginally over the past ten years (this finding may be influenced by the disciplinary focus of the research).

Finally, a promising direction for future research could be a cross-national review examining how CTL is implemented and adapted to local educational contexts across different countries (e.g., RANGKA strategy). The need for such research is underscored by the geographical concentration of existing studies: fourteen of the analyzed studies were conducted in Indonesia, while only two originated from other countries, namely New Zealand (Spooner, 2024) and Turkey (Yildiz & Baltaci, 2016).

DISCUSSION

The synthesize of the reviewed studies provides a comprehensive basis for addressing the RQs.

RQ1. How was the CTL approach conceptualized and implemented in research studies?

The findings demonstrate that incorporation of CTL into the educational process is not uniformly conceptualized in either literature or empirical studies. The studies reveal the existence of three levels of CTL implementation that differ in their degree of alignment with CTL incorporation as defined in the literature. Based on the analysis of the studies included, three levels of CTL incorporation into the educational process can be distinguished:

(1) direct implementation of the REACT strategy, in which CTL is applied through all of its components in accordance with the original sequential model,

(2) application of CTL components as defined by Johnson (2002), Hamruni (2012), and

(3) use of alternative instructional strategies, in which only selected CTL elements are implemented.

This stratification suggests that CTL is often adapted to suit specific classroom needs or research objectives, resulting in a spectrum of implementation rather than a singular standardized method.

RQ2. What specific CTL strategies have been identified as effective in teaching mathematics?

The reviewed studies identified several strategies that enhance effectiveness of mathematical instruction through CTL. the strategies relations to achieved educational effects and their position within Bloom's taxonomy is presented in the **Table 5**.

Although the reviewed studies (see **Table 5**) did not explicitly implement the REACT strategy, their instructional recommendations demonstrate strong conceptual alignment with its core components. Several proposed strategies - such as discussion and question posing (Ahdhianto et al., 2020; Lestari et al., 2021) and the creation of a learning environment that encourages the articulation of ideas and the development of mathematical reasoning (Nurlinda et al., 2024) correspond primarily to the Relating, Experiencing, Applying and Cooperating phases of the REACT strategy. These approaches emphasize active engagement with mathematical concepts through dialogue and exploration.

Similarly, the practice of initiating mathematics instruction with contextual problems drawn from real-life situations (Ekowati et al., 2015; Khotimah & Masduki, 2016) closely aligns with the Relating component, which serves as the entry point of the REACT sequence. The use of mathematical manipulatives as visual and concrete supports for abstract concepts (Ekowati et al., 2015), along with modelling activities that situate mathematics within meaningful contexts (Spooner, 2024), align with the experiencing and applying phases by facilitating conceptual understanding through hands-on and contextualized learning. Nurlinda et al. (2024) emphasize the importance of creating a learning atmosphere that enables students to express ideas and refine mathematical reasoning skills, referring to the Relating, Applying, and Cooperating phases.

Strategies such as making conclusions and generalizing solutions to analogous problems (Khotimah & Masduki, 2016) exemplify elements of the Transferring phase, as they require learners to extend mathematical understanding beyond the immediate instructional context. Finally, teacher improvisation aimed at reducing reliance on textbooks (Kurniansyah et al., 2022) aligns with the Experiencing and Transferring phases of the REACT strategy, as it encourages adaptive instruction and knowledge transfer across contexts. A more recent study by Mahmuti et al. (2025) provides quantitative evidence to confirm the effectiveness of an adopted and relabeled CTL approach in a specific classroom-based vocational economics mathematics context.

RQ3. What limitations and risks are associated with implementing CTL in mathematics instruction regarding the development of mathematical literacy?

Several conflicting findings emerge from the reviewed studies. For instance, Ahdhianto et al. (2020) report improvements in students' use of mathematical terminology and communication skills. In contrast, there is a study by Bitterlich (2020) (however, this study was not part of the analyzed sample). The author examined the effectiveness of teaching mathematics through CTL in 2nd grade elementary school pupils with a particular focus on the impact of contextualization on pupils' use of language and learning outcomes. Bitterlich (2020) identified key limitations of teachers' effort to explain content as illustratively as possible in a tendency to rely on deictic expressions and informal language, which led to a lack of exposure to exact mathematical terminology. According to Bitterlich (2020), a significant challenge for teachers lies in developing the competence to extract mathematically relevant ideas and present them to students in exact mathematical terminology. Despite these concerns, the author supports contextualized instruction. While Ahdhianto et al. (2020) evaluated student outcomes using quantitative measures of problem-solving and communication skills over a structured intervention, Bitterlich (2020) focused on qualitative analyses of classroom discourse and teacher language use. Furthermore, differences in teacher competency, task characteristics, and assessment instruments may have contributed to the divergent conclusions. Taken together, these studies indicate that the effectiveness of CTL in supporting mathematical communication depends on how contextualization is implemented and how subject-specific language is explicitly addressed within instruction.

Limitation of Study

The findings of the review should be interpreted with due consideration of its methodological limitations. First, the study was restricted to journals indexed in the WoS, Scopus, ERIC, and Google Scholar databases. Consequently, it does not encompass all existing research on the CTL approach. In addition, the inclusion of only English-language publications may have led to the omission of some relevant studies published in other languages. The exclusive focus on mathematics education further narrowed the scope of the reviewed literature. Moreover, the limited availability of advanced filtering options in some databases generated a large number of search results, many of which were unrelated to CTL and instead focused on general concepts of context and learning processes. This substantially prolonged the identification of relevant articles.

CONCLUSION

In summary, the existing reference literature on CTL demonstrates variability in how this approach is conceptualized and implemented, indicating differences in its application across the analyzed research studies. Given this diversity, consolidating current knowledge is essential for clarifying how CTL is operationalized in educational practice and for advancing further research in this field. The importance of this analysis lies in its identification of different levels of CTL implementation, which helps clarify inconsistencies in how CTL is applied in mathematics education and provides a more precise basis for future research. Future studies should particularly focus on CTL implementation in primary education, examine its application across different types of mathematics lessons, and explore how CTL-based instruction supports the development of mathematical concepts. The findings reveal three levels of CTL implementation that differ in their alignment with CTL principles:

(1) implementation of the REACT strategy, which follows the sequential model and incorporates all core components: relating, experiencing, applying, cooperating, and transferring,

(2) a less structured but more comprehensible application of CTL components based on the frameworks proposed by Johnson (2002) and Hamruni (2012), and

(3) the use of alternative eclectic instructional strategies that incorporate only selected CTL elements.

Despite these variations, the reviewed studies consistently reflect constructivist principles, which Crawford (2001) identifies as the core theoretical foundation of CTL. This study is also relevant in the national context, especially considering recent Slovak curriculum changes that emphasize learning for life and the integration of cross-curricular literacies, which can be supported through the CTL educational approach. By synthesizing existing research, this review provides a clearer overview of how CTL has been applied in mathematics education. Overall, the study contributes to a more coherent understanding of CTL implementation and offers a foundation for future empirical and theoretical research in this area.

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