

Synergy of 21st Century Skills (4C) and Mathematical Disposition in the Transformation of Innovative Mathematics Learning Models: A Systematic Literature Review

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Abstract

This study is motivated by the demands of 21st-century education, which emphasize the development of 4C skills (critical thinking, communication, collaboration, and creativity) alongside the importance of mathematical disposition as an affective factor supporting students' success in mathematics learning. However, studies integrating these two aspects within a unified instructional framework remain limited. Therefore, this study aims to examine research trends, analyze the relationship between mathematical disposition and 4C skills, and identify the most effective innovative learning models in fostering their synergy. This study employed a Systematic Literature Review (SLR) guided by the PRISMA protocol, analyzing 20 articles published within the last decade. Data were collected from reputable academic databases and analyzed using a qualitative descriptive approach through identification, screening, eligibility, and data extraction stages. The findings reveal a significant shift from a partial approach toward the integration of cognitive and affective aspects in mathematics learning. Mathematical disposition shows a positive and significant relationship with 4C skills, although its influence is context-dependent and mediated by factors such as self-efficacy and learning environment. Furthermore, innovative learning models such as Problem-Based Learning, Project-Based Learning, and Realistic Mathematics Education demonstrate more consistent effectiveness in fostering this synergy. This study implies that constructivist and collaborative learning approaches are essential to optimize both students' 4C skills and mathematical disposition.

Keyword: 4C Skills; Mathematical Disposition; Mathematics Learning; Innovative Learning



Models; Systematic Literature Review.

INTRODUCTION

The challenges of globalization in the 21st century have brought significant consequences to the field of education, where students are no longer sufficiently equipped with basic skills such as reading, writing, and arithmetic, but are also required to master 4C skills critical thinking, creative thinking, communication, and collaboration in order to compete in a global society (Dwi Rahma Putri et al., 2022). Mathematics, often referred to as the “Queen of Science,” plays a crucial role in developing logical, analytical, and systematic thinking skills that underpin advancements in information technology and automation (Dwi Rahma Putri et al., 2022; Saputra et al., 2026). However, empirical evidence indicates that students’ mathematical communication and problem-solving abilities remain unsatisfactory, which is often attributed to negative perceptions of mathematics as a difficult, monotonous, and abstract subject (Hasanah & Yayuk, 2025). This condition is further exacerbated by conventional teacher-centered instructional practices that focus primarily on algorithmic computation, thereby limiting students’ opportunities to actively and creatively express their ideas (Lubis et al., 2024).

The urgency of this study lies in the importance of establishing a synergy between cognitive achievement (4C skills) and affective aspects, particularly mathematical disposition, which refers to a conscious inclination to engage with, value, and utilize mathematics in a consistent and positive manner (Fahrudin et al., 2025; Febriyani et al., 2022). The literature consistently demonstrates a significant positive relationship between this mental attitude and academic success; students with high mathematical disposition tend to exhibit greater confidence, persistence, and curiosity, which in turn enhance their ability to solve complex problems and communicate effectively (Khoirunnisa et al., 2021). The transformation of mathematics education therefore requires the implementation of innovative learning models as catalysts, such as Problem-Based Learning (PBL), which promotes higher-order thinking and social skills; Discovery Learning, which encourages independent knowledge construction through exploration; and Realistic Mathematics Education (RME), which facilitates conceptual understanding through real-world contexts (Hasanah & Yayuk, 2025).

Despite the growing body of research on innovative learning models and mathematical disposition, a research gap remains, as existing studies are often fragmented or limited to specific populations. There is still a lack of systematic synthesis examining how the integration of 4C skills and mathematical disposition operates simultaneously within a unified framework of instructional transformation across different educational levels (Fahrudin et al., 2025).



Moreover, many previous studies tend to focus primarily on cognitive learning outcomes without sufficiently exploring how social interaction in collaborative settings mediates the development of students' positive character traits (Fahrudin et al., 2025; Manurung et al., 2025). Therefore, a comprehensive review is needed to map research trends and evaluate the effectiveness of various instructional models in fostering learning environments that support the holistic development of both cognitive and affective competencies.

This study aims to conduct a Systematic Literature Review (SLR) using the PRISMA protocol to examine relevant articles published over the past decade concerning the synergy between 4C skills and mathematical disposition. The primary focus of this study is to investigate how innovative learning models are implemented, evaluate their effectiveness in enhancing 21st-century competencies, and analyze the reciprocal relationship between students' mathematical disposition and their cognitive performance. Through this approach, the study seeks to generate coherent and meaningful insights that can serve as a reference for educators in designing instructional strategies aligned with the demands of the modern era.

Based on these objectives, this systematic literature review is designed to address three main research questions. First, what are the trends in research on 4C skills and mathematical disposition in mathematics education over the past decade? Second, to what extent does mathematical disposition influence the achievement of students' 4C skills based on existing empirical evidence? Third, which innovative learning models are identified as the most effective in fostering synergy between cognitive and affective aspects in the transformation of mathematics learning? By addressing these questions, this study aims to contribute to the development of more adaptive and inclusive theories and practices in mathematics education.

METHOD

This study employed a Systematic Literature Review (SLR) approach to systematically identify, examine, evaluate, and interpret relevant studies in a comprehensive and structured manner (Lubis et al., 2024). The review process was guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure methodological rigor, reliability, and to minimize bias in the identification and selection of literature (Baiti et al., 2025).

The primary data sources consisted of scientific articles published in reputable national and international academic databases, including Scopus, Google Scholar, ResearchGate, Garuda, ERIC, and ScienceDirect. The search strategy was conducted using combinations of relevant keywords, such as Discovery Learning, Communication, Collaboration, Problem-solving skills, Mathematical Disposition, and Student Performance, combined using Boolean operators. The



literature selection process followed the four main stages of the PRISMA framework: identification, screening, eligibility, and inclusion. Articles were evaluated based on predefined inclusion criteria to ensure relevance and quality in addressing the challenges of education in the era of globalization. Selected articles were then systematically extracted into a structured table format. The extracted data included author(s), publication year, research method, sample characteristics, and key findings. The data were analyzed using a qualitative descriptive approach by classifying findings, synthesizing relationships among variables, and drawing coherent conclusions to comprehensively address the research questions.

RESULTS AND DISCUSSION

The implementation of this Systematic Literature Review (SLR) began with the identification stage, involving a systematic search of relevant literature across reputable academic databases, including Google Scholar, Scopus, ResearchGate, and ERIC. The search process employed combinations of relevant keywords using Boolean operators (AND, OR), such as mathematical disposition, problem-solving skill, communication and collaboration skills, and innovative learning model. This strategy was designed to obtain comprehensive literature aligned with the focus of the study. Following the identification stage, a screening process was conducted to remove duplicate records and to select articles based on their titles and abstracts. At this stage, strict inclusion criteria were applied, including articles published in reputable national and international journals, written in either Indonesian or English, and published within the last ten years to ensure the relevance and recency of the data. Articles that did not meet these criteria such as conference proceedings, theses, or studies without full-text access were excluded from further analysis. The next stage involved eligibility assessment through an in-depth review of the full-text articles. Each selected study was critically examined to ensure that it explicitly addressed the relationship between 21st-century skills (4C) namely critical thinking, communication, collaboration, and creativity and mathematical disposition within the context of innovative learning models. This stage also considered methodological rigor, clarity of findings, and the contribution of each study to the advancement of mathematics education.

Based on the systematic and transparent selection process following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, a final set of articles that met all inclusion criteria was obtained. The subsequent stage involved data extraction, which was conducted systematically using a structured table format to facilitate organization and analysis. Extracted data included authors' identities, publication year, research design and methodology, sample characteristics, and key findings, as presented in Table 1. This



process aimed to identify patterns, trends, and research gaps, enabling the development of a comprehensive synthesis regarding the relationship between 4C skills and mathematical disposition within innovative mathematics learning contexts.

Table 1. Summary of Extraced Studies

No	Author(s) & Year	Research Method	Sampel	Key Findings
1	Ahmad & Nasution (2018)	Qualitative Descriptive Case Study	40 Junior High School Students	Realistic Mathematics Education (RME) improves students' mathematical communication skills.
2	Harianja (2020)	Mixed Methods	19 Junior High School Students	PjBL through math board game projects enhances creative thinking and communication skills.
3	Hasanah & Yayuk (2025)	Qualitative Descriptive	28 Elementary School Students	RME approach improves student collaboration up to level 4 based on the CLD rubric.
4	Herdiansyah (2025)	Classroom Action Research (CAR)	38 Senior High School Students	PBL significantly optimizes students' collaboration skills.
5	Khoirunnisa et al. (2021)	Quantitative (Survey)	53 MTs Students	A positive and significant relationship exists between mathematical disposition and communication skills.
6	A. A. Lestari & Adirakasiwi (2022)	Qualitative Descriptive	30 Junior High School Students	Students with high disposition meet all indicators of mathematical communication.
7	I. Lestari & Andinny (2023)	Quantitative (Regression)	90 Students	Mathematical disposition has a significant effect on problem-solving ability.
8	Lubis et al. (2024)	Systematic Literature Review (SLR)	25 Articles	Various innovative models (TTW, TPS, PBL) effectively improve mathematical communication.
9	Manurung et al.	Classroom	17 Senior High	TGT with Card Sort improves

No	Author(s) & Year	Research Method	Sampel	Key Findings
	(2025)	Action Research (CAR)	School Students	collaboration from low to very good levels.
10	Rezita & Rahmat (2022)	Quantitative (Correlational)	21 Senior High School Students	A strong positive correlation ($r = 0.691$) exists between mathematical disposition and problem-solving ability.
11	Ruhiyat & Sugandi (2017)	Quantitative (Associative)	46 Junior High School Students	There is a moderate association between creative thinking ability and mathematical disposition.
12	Pendidikan & Saputra (2026)	Classroom Action Research (CAR)	20 MA Students	Team Teaching collaboration improves students' motivation and learning engagement.
13	H. M. Siregar (2023)	Systematic Literature Review (SLR)	13 Articles	ESD implementation in mathematics enhances soft skills (communication, collaboration, disposition).
14	Akbar et al. (2017)	Qualitative Descriptive	20 Senior High School Students	50% of students have low mathematical disposition, hindering problem-solving ability.
15	Anderha & Maskar (2020)	Qualitative Analysis	5 Senior High School Students	Mathematical communication in online learning varies depending on task indicators.
16	Baiti et al. (2025)	Systematic Literature Review (PRISMA Protocol)	6 Final Articles	Discovery Learning improves collaboration (responsibility, flexibility) and communication skills.
17	Dwi Rahma Putri et al. (2022)	Descriptive Analysis	Journal Articles	21st-century mathematics learning must emphasize 4C skills to address global challenges.

No	Author(s) & Year	Research Method	Sampel	Key Findings
18	Fahrudin et al. (2025)	Systematic Literature Review (PRISMA Protocol)	15 Final Articles	A significant relationship exists between mathematical disposition and problem-solving success.
19	Fairus et al. (2023)	Qualitative Descriptive	30 Vocational High School Students	Students' mathematical disposition is generally at low to moderate levels.
20	Febriyani et al. (2022)	Quantitative (Survey)	26 Junior High School Students	Mathematical disposition has a positive but non-significant effect on conceptual understanding.

The results of the qualitative descriptive analysis of the 20 selected articles provide a comprehensive synthesis addressing the three main research questions.

Trends in Research on 4C Skills and Mathematical Disposition

Over the past decade, research trends in mathematics education in Indonesia have shown a clear shift from conventional teacher-centered approaches toward innovative learning transformations that position students as active participants in the learning process (Ahmad & Nasution, 2018). This transformation is evident not only in methodological aspects but also in the research focus, which increasingly emphasizes the integration of 21st-century skills (4C) and mathematical disposition. Dwi Rahma Putri et al. (2022) assert that 21st-century mathematics learning must incorporate critical thinking, communication, collaboration, and creativity to address global demands, similarly Baiti et al. (2025) through bibliometric mapping using VOSviewer, identified keywords such as discovery, communication, and collaboration as central themes in recent research trends. This indicates a growing orientation toward constructivist and collaborative learning approaches. A closer examination reveals that this development has occurred gradually. In the earlier period (approximately 2014–2018), research primarily focused on examining the basic relationship between mathematical disposition and cognitive abilities, such as creative thinking and problem-solving (Akbar et al., 2017; Ruhayat & Sugandi, 2017). During this phase, studies were predominantly quantitative, employing correlational and descriptive approaches. However, since 2020, there has been a significant shift toward more integrative research, characterized by the increasing use of innovative learning models such as



Problem-Based Learning, Project-Based Learning, and Realistic Mathematics Education, which simultaneously promote the development of 4C skills and mathematical disposition (Fahrudin et al., 2025; Harianja, 2020; I. Lestari & Andinny, 2023; Lubis et al., 2024). Furthermore, between 2014 and 2024, mathematical disposition has increasingly been positioned as a key variable contributing to students' success in mathematical problem-solving (Fahrudin et al., 2025). These findings reflect a broader shift from a purely cognitive focus toward the integration of affective dimensions in mathematics learning. This shift can also be interpreted as a response to the relatively low levels of students' mathematical literacy reported in international assessments, prompting researchers to emphasize the importance of character development, positive attitudes, and self-confidence in learning mathematics.

Based on this overall synthesis, the authors argue that research trends have evolved from a partial approach toward a more holistic and integrative perspective, in which mathematical disposition is no longer viewed as a supporting variable but rather as a central component in shaping and strengthening 4C skills within the transformation of mathematics learning.

The Relationship Between Mathematical Disposition and the Achievement of 4C Skills

The synthesis of findings indicates that most studies report a positive relationship between mathematical disposition and 21st-century skills (4C), although the level of significance varies across studies. Quantitative research consistently demonstrates that mathematical disposition significantly contributes to students' communication and mathematical problem-solving abilities (Khoirunnisa et al., 2021; I. Lestari & Andinny, 2023; Rezita & Rahmat, 2022). Notably, Lestari & Andinny (2023) found that mathematical disposition accounts for 53.8% of the variance in problem-solving ability. These findings reinforce the assumption that mathematical disposition functions as a crucial affective factor supporting the development of students' cognitive skills. Furthermore, more specific insights reveal that one key component of mathematical disposition, namely self-efficacy, influences students' communication profiles. Students with high self-efficacy tend to be more dominant in oral communication, whereas those with lower self-efficacy rely more on written communication. However, the findings are not entirely consistent across all studies. For instance, Febriyani et al. (2022) reported that mathematical disposition has a positive but non-significant effect on conceptual understanding. These discrepancies may be attributed to several factors, including differences in sample characteristics (such as age and prior ability), measurement instruments, and instructional contexts (conventional versus innovative learning environments). Additionally, external factors such as school regulations and students' psychological conditions during adolescence may



influence the stability of mathematical disposition in the learning process. Qualitative findings further support these results, indicating that students with high mathematical disposition tend to be more active in communication, collaboration, and the exploration of mathematical ideas (A. A. Lestari & Adirakasiwi, 2022) whereas students with low disposition tend to be passive and lack confidence in solving problems (Akbar et al., 2017).

Based on this overall synthesis, the authors argue that mathematical disposition is a strong predictor of the achievement of 4C skills, although it does not operate independently. Instead, it interacts with various other factors, such as self-efficacy, learning environment support, and the teacher's role in creating a conducive learning atmosphere. Therefore, the development of 4C skills cannot be separated from continuous and contextual efforts to foster students' mathematical disposition.

Effectiveness of Innovative Learning Models in Educational Transformation

The synthesis of the reviewed studies indicates that innovative learning models demonstrate varying levels of effectiveness in fostering synergy between students' cognitive and affective domains, with each model offering distinct advantages based on its characteristics. Problem-Based Learning (PBL) is identified as one of the most consistent approaches in enhancing communication, collaboration, and problem-solving skills due to its emphasis on engaging students in solving authentic problems collaboratively (Herdiansyah, 2025; T. Siregar, 2025). In contrast, Project-Based Learning (PjBL) is particularly effective in promoting creativity and student engagement through contextual, project-based activities (Harianja, 2020). Meanwhile, Realistic Mathematics Education (RME/PMR) demonstrates strong effectiveness in developing conceptual understanding and mathematical communication through real-world contexts, and has been shown to improve students' collaboration to higher levels based on 21st-century learning indicators (Ahmad & Nasution, 2018; Hasanah & Yayuk, 2025). In addition to these primary models, other approaches such as Discovery Learning and Teams Games Tournament (TGT) also contribute positively, albeit with different strengths. Discovery Learning is effective in fostering students' independence and responsibility through structured exploration processes (Baiti et al., 2025), while TGT, supported by instructional media such as Card Sort, enhances active participation and social interaction among students who were previously passive (Manurung et al., 2025). However, the effectiveness of these models is not always consistent, as it is strongly influenced by factors such as implementation quality, student readiness, and the learning environment. In some cases, both Discovery Learning and



conventional instructional approaches yield suboptimal outcomes when not supported by appropriate strategies (Baiti et al., 2025; T. Siregar, 2025).

Based on this overall synthesis, the authors argue that no single learning model can be considered universally superior; rather, its effectiveness is context-dependent. Nevertheless, problem-based and project-based approaches, particularly PBL and PjBL, demonstrate the highest consistency in integrating cognitive aspects (such as critical thinking and problem-solving) with affective aspects (such as mathematical disposition, motivation, and collaboration). This is reinforced by the inherent characteristics of these models, which promote active student engagement both intellectually and emotionally in the learning process. Therefore, innovative learning models that are constructivist, contextual, and collaborative in nature can be considered the most relevant approaches for supporting the holistic transformation of mathematics education in the modern era.

CONCLUSION

Based on the overall findings of the Systematic Literature Review (SLR) analyzed using the PRISMA approach, a comprehensive synthesis reveals that research on 21st-century skills (4C) and mathematical disposition has undergone a significant shift toward a more integrative approach. Research trends are no longer partially focused on cognitive aspects alone but have evolved to incorporate both cognitive and affective dimensions simultaneously within mathematics learning. Mathematical disposition has been shown to have a strong relationship with 4C skills, particularly communication, collaboration, and problem-solving, although its influence is context-dependent and mediated by factors such as self-efficacy, learning environment, and instructional strategies. Furthermore, innovative learning models such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Realistic Mathematics Education (RME) demonstrate relatively consistent effectiveness in fostering synergy between cognitive and affective domains compared to other instructional approaches. From a scientific contribution perspective, this study reinforces the conceptual framework that mathematical disposition is not merely a supporting variable but a core component in the development of 4C skills. Additionally, this review enriches the existing literature by providing a comprehensive synthesis of the relationship between mathematical disposition, 21st-century skills, and the effectiveness of various innovative learning models, particularly within the context of mathematics education in Indonesia. Therefore, the findings of this study can serve as a theoretical reference for the development of more holistic and 21st-century-oriented instructional models. From a practical standpoint, the findings emphasize the crucial role of



teachers in designing learning environments that not only target cognitive achievement but also strengthen students' mathematical disposition. Educators are encouraged to implement constructivist and collaborative learning models, such as PBL and PjBL, as well as to integrate real-world contexts as promoted in RME to enhance student engagement. Moreover, it is essential to create a supportive learning environment that fosters students' confidence, motivation, and social interaction in order to optimize the development of 4C skills. However, this study has several limitations. These include the relatively limited number of articles analyzed (20 studies) and the dominance of qualitative and descriptive research designs, which may restrict the generalizability of the findings. In addition, variations in research instruments and learning contexts across studies may affect the consistency of the synthesized results. This study also does not fully incorporate advanced quantitative analyses such as meta-analysis, which could provide more precise effect estimates. Based on these limitations, future research is recommended to employ experimental quantitative approaches and meta-analytic methods to further examine the influence of mathematical disposition on 4C skills. Additionally, future studies may explore the role of mediating variables such as self-efficacy, learning motivation, and environmental support in strengthening this relationship. Cross-level studies across different educational stages and the integration of artificial intelligence-based technologies in mathematics learning also present promising directions for supporting more adaptive and sustainable educational transformation..

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