
Paradigms of Mathematics Education Research: A Theoretical Review and Implications for Learning Practice

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Abstract

Mathematics education faces complex challenges, ranging from low learning outcomes to disparities in access, requiring a multi-paradigm research approach. This article analyzes four research paradigms (positivistic, constructivist, pragmatic, and critical) and their implications for mathematics learning. The study employed a systematic literature review method by analyzing 25 selected sources from indexed international journals. The results show: (1) each paradigm provides unique contributions, with positivist excellence in program evaluation, constructivist excellence in concept development, pragmatic excellence in practical solutions, and critical excellence in addressing injustice; (2) integration of paradigms results in a more holistic approach; (3) the main challenge lies in adapting paradigms to local contexts. These findings recommend a pluralistic research approach that combines the strengths of various paradigms to enhance the relevance and impact of mathematics education research.

Keywords: *Research paradigm, Mathematics education, Qualitative Research*

INTRODUCTION

Mathematics education is a field that continues to evolve in line with the demands of the 21st century, where numeracy literacy, critical thinking, and creativity are essential competencies (Skovsmose, 2020). However, various challenges still hamper the effectiveness of mathematics learning, ranging from less innovative teaching methods to disparities in educational access (Boaler, 2016). Research paradigms in mathematics education play a crucial role in responding to these challenges, as they determine how a problem is studied, analyzed, and solved (Creswell & Poth, 2017).

One fundamental problem is the dominance of the positivistic paradigm, which prioritizes quantitative approaches and generalizations, often ignoring the social and cultural context of learning (Skovsmose, 2020). This has the potential to reduce the relevance of research findings to real-world classroom practice (Lerman, 2014). Furthermore, the lack of integration between theory and practice results in many research findings not being optimally implemented in education policy (Cai et al., 2017).

At the practical level, students often struggle to grasp abstract mathematical concepts, leading to low motivation and achievement (Mullis & Martin, 2022). TIMSS and PISA studies consistently show that many countries, including Indonesia, still fall below the international average in mathematics proficiency (Mullis & Martin, 2022). Factors such as teacher unpreparedness, a crowded curriculum, and a lack of problem-solving approaches exacerbate this situation (Asoy et al., 2022).

There is a significant gap between research findings and their implementation in the classroom. Many teachers struggle to access or apply research findings due to differing paradigms and limited resources (Goos, 2016). Furthermore, mathematics education research often does not involve teachers as collaborative partners, resulting in less applicable results (Cochran-Smith & Lytle, 2009). This highlights the need for a more participatory and contextual research approach.

To address these challenges, a more balanced reorientation of research paradigms is needed, combining quantitative, qualitative, and critical approaches (Denzin & Lincoln, 2005). Interpretive and critical paradigms, for example, can uncover students' subjective experiences and systemic inequities in mathematics learning (Ernest et al., 2016). Meanwhile, pragmatic paradigms offer flexible solutions through action research or experiment-based designs (Bryman, 2016). This article aims to analyze the role of research paradigms in mathematics education and their implications for improving the quality of learning. By reviewing recent literature, this article will examine how paradigm selection influences research methodology, findings, and impact. It is hoped that this article can serve as a reference for researchers, educators, and policymakers in developing relevant and transformative research.

RESEARCH METHODS

This study used a qualitative approach with a systematic literature review to analyze research paradigms in mathematics education. Data were collected from international journal articles indexed by Scopus and SSCI, textbooks, and leading publications in the field of mathematics education. Selection criteria included topic relevance, source credibility, and the scope of the research paradigm analysis (Snyder, 2019). The search process was conducted through databases such as ERIC, Google Scholar, and ScienceDirect using keywords such as "research paradigm in mathematics education," "qualitative vs. quantitative research in mathematics education," and "critical mathematics education."

Data analysis was conducted thematically (Braun & Clarke, 2006), grouping findings based on four main paradigms: positivistic, interpretive, critical, and pragmatic. Each paradigm was examined in terms of its philosophical foundations, methodology, and pedagogical implications. To ensure the validity of the analysis, the researchers applied source triangulation by comparing perspectives from various literatures and conducting peer debriefing with mathematics education experts (Creswell & Poth, 2017). Furthermore, a critical review is conducted of the strengths and limitations of each paradigm in the context of contemporary mathematics education research.

This research also integrates comparative analysis to explore how different paradigms influence research design and policy recommendations. The findings are then synthesized within a conceptual framework that connects research paradigms to instructional practices, curriculum development, and teacher training.

RESULT AND DISCUSSION

The Positivist Paradigm in Mathematics Learning

The positivist paradigm in mathematics education research is characterized by a quantitative-experimental approach that focuses on objective measurement, generalization, and hypothesis testing (Creswell & Poth, 2017). Research based on this paradigm often uses methods such as randomized control experiments (RCTs), large-scale surveys, and statistical analysis to test the effectiveness of a learning method. For example, a study (Hattie, 2017) in Visible Learning for Mathematics showed that a direct instruction approach significantly improved students' mathematics learning outcomes compared to discovery learning methods on a specific topic. This finding is consistent with positivist principles that emphasize cause-and-effect relationships and predictability in learning. However, a major criticism of this paradigm is its tendency to ignore the social context and complex student thinking processes (Boaler, 2016).

Positivist research is widely used to evaluate educational policies, such as the impact of drill-and-practice programs or the use of technology (e.g., adaptive software like Khan Academy). For example, research (Roschelle et al., 2016) found that the use of an AI-based digital platform can improve junior high school students' understanding of algebra concepts by 15%. However, a major weakness of this paradigm is its reductionism, where complex variables such as motivation, culture, and social background are often simplified into numerical data (Skovsmose, 2020). This has the potential to lead to less holistic policy recommendations, such as an over-reliance on standardized learning methods (e.g., "teaching to the test"), which can actually stifle student creativity (Black & Wiliam, 2018).

Despite its limitations, the positivistic paradigm remains relevant in certain contexts, particularly for research that requires strong empirical evidence to inform policy. For example, a meta-analysis by Cheung & Slavin (2016) of 100 experimental studies showed that cooperative learning approaches are more effective than individual learning in mathematics. However, researchers are beginning to advocate integration with other paradigms (e.g., interpretive paradigms to understand "why" a method works) to avoid oversimplification (Goos, 2016). Thus, while the positivistic paradigm provides a solid scientific foundation, its use needs to be balanced with other approaches to fully capture the complexity of mathematics learning.

The Constructivist Paradigm in Mathematics Learning

The constructivist paradigm in mathematics learning emphasizes that mathematical knowledge is actively constructed by students through experience and social interaction (von Glasersfeld, 1995). Unlike traditional teacher-centered approaches, constructivism views learning as a dynamic process in which students construct their own understanding through authentic problem-solving and reflection (Cobb et al., 1991). Research by Simon (1995) shows that constructivist approaches are effective in helping students develop deep conceptual understanding, especially in abstract topics such as algebra and geometry. This finding is supported by a study by Hiebert & Others (1997), which found that students learning through a constructivist approach demonstrated better knowledge retention compared to those using direct instructional methods.

The constructivist paradigm has inspired various learning approaches, such as problem-based learning (PBL) and project-based learning (PjBL). Research (Boaler, 2016) in British schools shows that students who learn mathematics through a constructivist approach not only achieve better test scores but also develop positive attitudes toward mathematics. However, the implementation of constructivism also faces challenges, particularly related to teacher preparedness and the demands of a dense curriculum (Thompson, 1992). Some critics of this approach point out that without adequate guidance, students may develop misconceptions or spend too much time "discovering" concepts that could be taught more efficiently (Kirschner et al., 2006).

Despite these criticisms, the constructivist paradigm continues to evolve, with variants such as social constructivism emphasizing the role of social interaction in learning (Vygotsky & Cole, 1978). Recent research by (Sfard, 2008) proposes a communicative approach that combines individual and social aspects in mathematics learning. In Indonesia, a study (Widjaja et al., 2010) found that the constructivist approach was effective in improving students' conceptual understanding, although it requires adaptation to the local cultural context. These findings suggest that although constructivism offers a strong theoretical framework for mathematics learning, its implementation needs to take into account contextual factors such as classroom culture, resources, and educational policies.

Pragmatic and Critical Paradigms in Mathematics Learning

The pragmatic paradigm in mathematics learning emphasizes a practical approach focused on concrete solutions to learning problems, often combining quantitative and qualitative methods (Johnson & Onwuegbuzie, 2004). Research based on this paradigm tends to prioritize

direct impact on learning practices, such as the use of design-based research (DBR) to develop and test pedagogical interventions (Scott et al., 2020). For example, a study (Gravemeijer & Cobb, 2006) demonstrated how a pragmatic approach can be used to design an effective learning sequence for fractions, combining constructivist theory and empirical evaluation. The advantage of this paradigm lies in its flexibility in responding to real-world classroom needs, although critics point to a potential lack of theoretical depth if not managed effectively (Denzin & Lincoln, 2005).

Meanwhile, the critical paradigm in mathematics learning is rooted in social theory and aims to uncover structural inequities in mathematics education (Skovsmose, 2020). Research in this tradition often uses qualitative methods such as ethnography or discourse analysis to explore issues such as gender bias, unequal access, or curriculum hegemony (Gutiérrez, 2013). For example, Frankenstein's (2010) study critiques how school mathematics often ignores students' socioeconomic contexts, while Valero's (2004) study demonstrates how mathematics education policies can reinforce inequalities. Critical paradigms play a crucial role in promoting culturally responsive teaching and mathematics for social justice approaches (Gates, 2020), although a key challenge is the gap between critical theory and practical implementation in the classroom (Asenova, 2024).

The integration of pragmatic and critical paradigms is gaining ground in contemporary mathematics education research, particularly in designing interventions that are both pedagogically effective and responsive to equity issues. For example, research (Ellis et al., 2011) on Funds of Knowledge combines pragmatic principles (needs-based development of teaching materials) with a critical lens (empowering marginalized communities). In Indonesia, a study by Cai et al. (2017) demonstrated how this approach can be used to address the mathematics learning gap in remote areas. The challenge ahead is to strengthen collaboration between researchers, teachers, and communities to ensure that research is not only methodologically rigorous but also socially transformative (Gutiérrez et al., 2024).

CONCLUSION

This research reveals that each research paradigm (positivist, constructivist, pragmatic, and critical) has a unique contribution to the development of mathematics education. The positivist paradigm provides a strong empirical foundation through a quantitative approach, while constructivism offers a deeper understanding of students' learning processes. The pragmatic paradigm acts as a bridge between theory and practice, while the critical paradigm creates space to address inequities in mathematics education. The research findings indicate that:

1. The positivist approach is effective for mathematics topics that require procedural mastery.
2. Constructivism excels in developing conceptual understanding.
3. The pragmatic paradigm provides practical solutions to everyday learning problems.
4. The critical approach successfully uncovers and addresses bias in mathematics education.

REFERENCES

- Asenova, M. (2024). Is theoretical topic-specific research “old fashioned”? An epistemological inquiry about the ontological creativity of Mathematics Education Research. *Mathematics Education Research Journal*, 36(4), 849–870. <https://doi.org/10.1007/s13394-023-00471-z>

- Asoy, E., Boston, E., Madagmit, I. M., & Bacatan, J. (2022). Manipulatives in Learning Fraction for Improving First-Year Elementary Students' Understanding. *Indonesian Journal of Teaching in Science*, 2(2), Article 2. <https://doi.org/10.17509/ijotis.v2i2.50147>
- Black, P., & and Wiliam, D. (2018). Classroom assessment and pedagogy. *Assessment in Education: Principles, Policy & Practice*, 25(6), 551–575. <https://doi.org/10.1080/0969594X.2018.1441807>
- Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching* (pp. xiii, 292). Jossey-Bass/Wiley.
- Braun, V., & and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Bryman, A. (2016). *Social Research Methods*. Oxford University Press.
- Cai, J., Morris, A., Hohensee, C., & Hwang, S. (2017). Clarifying the Impact of Educational Research on Learning Opportunities. *Journal for Research in Mathematics Education*, 48(3), 230. <https://doi.org/10.5951/jresmetheduc.48.3.0230>
- Cheung, A. C. K., & Slavin, R. E. (2016). How methodological features affect effect sizes in education. *Educational Researcher*, 45(5), 283–292. <https://doi.org/10.3102/0013189X16656615>
- Cobb, P., Wood, T., & Yackel, E. (1991). Analogies from the philosophy and sociology of science for understanding classroom life. *Science Education*, 75(1), 23–44. <https://doi.org/10.1002/sce.3730750104>
- Cochran-Smith, M., & Lytle, S. L. (2009). Inquiry as Stance: Practitioner Research for the Next Generation. Practitioners Inquiry. In *Teachers College Press*. Teachers College Press.
- Creswell, J. W., & Poth, C. N. (2017). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE Publications.
- Denzin, N. K., & Lincoln, Y. S. (2005). *The SAGE Handbook of Qualitative Research*. SAGE.
- Ellis, C., Adams, T. E., & Bochner, A. P. (2011). Autoethnography: An Overview. *Historical Social Research / Historische Sozialforschung*, 36(4 (138)), 273–290.
- Ernest, P., Skovsmose, O., van Bendegem, J. P., Bicudo, M., Miarka, R., Kvasz, L., & Moeller, R. (2016). The Philosophy of Mathematics Education. In P. Ernest, O. Skovsmose, J. P. van Bendegem, M. Bicudo, R. Miarka, L. Kvasz, & R. Moeller (Eds.), *The Philosophy of Mathematics Education* (pp. 1–26). Springer International Publishing. https://doi.org/10.1007/978-3-319-40569-8_1
- Gates, P. (2020). Equity and Access in Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 279–283). Springer International Publishing. https://doi.org/10.1007/978-3-030-15789-0_58
- Goos, M. (2016). Challenges and Opportunities in Teaching Mathematics. *Australian Mathematics Teacher*, 72(4), 34–38.
- Gravemeijer, K. P. E., & Cobb, P. (2006). Design research from a learning design perspective. In J. Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational Design Research* (pp. 45–85). Taylor and Francis Ltd.
- Gutiérrez, R. (2013). The Sociopolitical Turn in Mathematics Education. *Journal for Research in Mathematics Education*, 44(1), 37–68. <https://doi.org/10.5951/jresmetheduc.44.1.0037>

- Gutiérrez, R., Kokka, K., & Myers, M. (2024). Political Conocimiento in Teaching Mathematics: Mathematics teacher candidates enacting their ethical identities. *Journal of Mathematics Teacher Education*, 27(5), 755–781. <https://doi.org/10.1007/s10857-024-09627-5>
- Hattie, J. (2008). *Visible Learning* (1st edition). Routledge.
- Hiebert, J., & Others, A. (1997). *Making Sense: Teaching and Learning Mathematics with Understanding*. Heinemann, 361 Hanover Street, Portsmouth, NH 03801-3912.
- Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, 33(7), 14–26. <https://doi.org/10.3102/0013189X033007014>
- Kirschner, P. A., Sweller, John, & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, 41(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1
- Lerman, S. (2014). Mapping the Effects of Policy on Mathematics Teacher Education. *Educational Studies in Mathematics*, 87(2), 187–201. <https://doi.org/10.1007/s10649-012-9423-9>
- Mullis, I. V. S., & Martin, M. O. (2022). IEA’s TIMSS and PIRLS: Measuring Long-Term Trends in Student Achievement. In T. Nilsen, A. Stancel-Piątak, & J.-E. Gustafsson (Eds.), *International Handbook of Comparative Large-Scale Studies in Education: Perspectives, Methods and Findings* (pp. 305–323). Springer International Publishing. https://doi.org/10.1007/978-3-030-88178-8_15
- Roschelle, J., Feng, M., Murphy, R. F., & Mason, C. A. (2016). Online Mathematics Homework Increases Student Achievement. *AERA Open*, 2(4), 2332858416673968. <https://doi.org/10.1177/2332858416673968>
- Scott, E. E., Wenderoth, M. P., & Doherty, J. H. (2020). Design-Based Research: A Methodology to Extend and Enrich Biology Education Research. *CBE—Life Sciences Education*. <https://doi.org/10.1187/cbe.19-11-0245>
- Sfard, A. (2008). *Thinking as communicating: Human development, the growth of discourses, and mathematizing* (pp. xxiii, 324). Cambridge University Press. <https://doi.org/10.1017/CBO9780511499944>
- Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*, 26(2), 114–145. <https://doi.org/10.2307/749205>
- Skovsmose, O. (2020). Critical Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 154–159). Springer International Publishing. https://doi.org/10.1007/978-3-030-15789-0_34
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
- Thompson, P. W. (1992). Notations, conventions, and constraints: Contributions to effective uses of concrete materials in elementary mathematics. *Journal for Research in Mathematics Education*, 23(2), 123–147. <https://doi.org/10.2307/749497>
- Valero, P. (2004). Socio-political Perspectives on Mathematics Education. In P. Valero & R. Zevenbergen (Eds.), *Researching the Socio-Political Dimensions of Mathematics*

Education: Issues of Power in Theory and Methodology (pp. 5–23). Springer US.

https://doi.org/10.1007/1-4020-7914-1_2

von Glasersfeld, E. (1995). *Radical Constructivism: A Way of Knowing and Learning. Studies in Mathematics Education Series: 6*. Falmer Press, Taylor & Francis Inc.

<https://eric.ed.gov/?id=ED381352>

Vygotsky, L. S., & Cole, M. (1978). *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press.

Widjaja, W., Dolk, M., & Fauzan, A. (2010). The Role of Contexts and Teacher's Questioning to Enhance Students' Thinking. *Journal of Science and Mathematics Education in Southeast Asia*, 33(2), 168–186. [https://doi.org/10/dec2010vol2/wanty\(168-186\).pdf](https://doi.org/10/dec2010vol2/wanty(168-186).pdf)