

Research Article

Paradigm Change in Western Mathematical Thinking and its Impact in Philosophy of Mathematics

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ABSTRACT

This study examines paradigm changes in Western mathematical thought and their implications for the philosophy of mathematics, curriculum, and pedagogy. Employing a qualitative narrative literature review with historical-conceptual analysis and thematic synthesis, the study traces major transformations across premodern, modern, and postmodern paradigmatic orientations. The findings show that premodern thought was broadly characterized by cosmic harmony, essentialism, and an ordered conception of reality in which mathematical knowledge was closely associated with metaphysical and theological understandings. Modernism marked a major transformation through the scientific revolution, the mathematization of nature, and the development of mechanistic and rationalist approaches to knowledge. The contributions of Descartes and Newton were particularly influential in strengthening mathematics as a means of explaining and organizing the natural world and in reinforcing ideals of rationality, certainty, and systematic order. Postmodern thought subsequently challenged assumptions of universality, certainty, and linearity by emphasizing complexity, contextuality, plurality, and the constructed nature of knowledge. These paradigm changes also influenced educational thought. Modernist assumptions were reflected in technical rationality, linear curriculum organization, and predetermined learning outcomes, whereas later perspectives increasingly emphasized biological and cognitive views of development, interaction, transformation, and more flexible approaches to learning. The ideas associated with Piaget and Bruner further highlighted the developmental, constructive, and interactive character of learning, while postmodern curriculum perspectives introduced nonlinear and emergent conceptions of educational development, including the notion of chaotic order and a movement toward dialogical and participatory pedagogy. Overall, the review indicates that transformations in mathematical philosophy are closely interconnected with broader changes in Western epistemology and with corresponding shifts in curriculum and pedagogical thought.

Keywords: Curriculum; Modernism; Paradigm Shift; Philosophy of Mathematics; Postmodernism.

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1. Introduction

The historical development of mathematical thought is not merely a cumulative record of concepts, techniques, and theorems; it also reflects broader transformations in how reality, knowledge, certainty, and human reasoning have been understood. Changes in mathematical thought have frequently occurred alongside shifts in philosophical and scientific worldviews, making the history of mathematics inseparable from wider epistemological and ontological developments. In accounts of Western intellectual history, these transformations are often discussed through three broad paradigmatic orientations—premodernism, modernism, and postmodernism—which

provide an analytical framework for examining changing assumptions about reality, knowledge, and mathematical truth (Gnawali, 2024; Subedi, 2025). Although these paradigms should not be understood as rigid or mutually exclusive historical periods, they offer a useful framework for tracing major changes in the philosophical foundations of mathematical thought.

Premodern Western thought was broadly associated with conceptions of an ordered and intelligible cosmos in which knowledge was situated within wider metaphysical and theological structures. The transition toward early modern thought, however, involved substantial changes in the understanding of nature and the methods through which reliable knowledge could be established. Osler (2010) characterizes the development of early modern science as a complex transformation in European understandings of nature, God, and human knowledge rather than as a simple replacement of one worldview by another. Similarly, Dear (1995) demonstrates that the Scientific Revolution involved changing relations among mathematics, experience, experiment, and natural philosophy. The increasing mathematization of nature was particularly significant, as mathematical reasoning came to occupy a more central position in explanations of the physical world. Within this transformation, Descartes played an especially influential role by linking mathematics, method, metaphysics, and the pursuit of certainty, while also making substantial contributions to mathematics and natural philosophy (Hatfield, 2017). These developments contributed to a modern intellectual orientation characterized by rationalization, methodological control, and an increasing confidence in systematic and formally organized knowledge.

Modernity consequently strengthened an image of knowledge as orderly, rational, and potentially universal. Such an orientation extended beyond mathematics and natural science into broader institutional and educational practices. Feenberg (2011), for example, describes modernity as strongly associated with rationalized institutions, arrangements, and technologies, while Matthews (2009) emphasizes the importance of philosophical and worldview assumptions in understanding scientific knowledge and its educational implications. Within curriculum theory, Doll (1989, 1993) associates modernist thinking with linearity, predictability, predetermined objectives, and cumulative conceptions of development. From this perspective, the influence of modern mathematical and scientific rationality was not limited to the production of knowledge; it also shaped ways of organizing knowledge for teaching and learning.

The presumed stability and universality of modern knowledge, however, became increasingly contested. Twentieth-century intellectual developments raised important questions about certainty, completeness, objectivity, and the relationship between formal systems and the realities they seek to represent. In mathematics, Gödel's incompleteness theorems became particularly significant in philosophical discussions because they demonstrated limitations internal to sufficiently powerful formal axiomatic systems, thereby complicating strong claims about complete and self-sufficient mathematical foundations (Subedi, 2025). More broadly, postmodern thought challenged universalizing accounts of knowledge and drew greater attention to plurality, context, interpretation, and the limits of overarching explanatory frameworks. Lyotard and Van Den Abbeele (1984) represent part of this wider intellectual discussion concerning postmodernity and the instability of comprehensive philosophical narratives.

These changes also generated important consequences for curriculum and pedagogy. Doll's postmodern curriculum perspective shifts attention from linear accumulation toward interaction, emergence, transformation, complexity, and open-ended development (Doll, 1989, 1993). Trueit (2012) further situates Doll's work at the intersection of pragmatism, postmodernism, complexity theory, and the educational ideas of Dewey, Piaget, Bruner, and Whitehead. Within this broader shift, knowledge

and learning are increasingly understood as developmental and interactive rather than as the passive acquisition of fixed and isolated units of information. Piagetian theory, for example, conceptualizes cognitive development through processes of adaptation, reorganization, and equilibration (Kazi & Galanaki, 2020), while research on mathematical understanding has emphasized that the development of understanding is recursive and dynamic rather than strictly linear (Pirie & Kieren, 1994). Discussions of curriculum theory have similarly highlighted the importance of constructivist, psychocultural, process-oriented, and postmodern perspectives in challenging narrowly technical conceptions of teaching and learning (Scott, 2007).

Despite these substantial bodies of scholarship, the relationships among changes in Western philosophical paradigms, changing conceptions of mathematical knowledge, and their subsequent implications for curriculum and pedagogy are often discussed in separate strands of literature. Historical studies illuminate transformations in mathematics and natural philosophy (Dear, 1995; Osler, 2010), philosophical studies address questions of rationality, certainty, and knowledge (Feenberg, 2011; Hatfield, 2017; Subedi, 2025), while curriculum scholarship explores the movement from linear and technically rational models toward more complex, transformative, and participatory approaches (Doll, 1989, 1993; Scott, 2007; Trueit, 2012). What remains less explicitly synthesized is how these developments can be understood as interconnected dimensions of broader paradigmatic change. An integrated historical-conceptual account is therefore needed to clarify how transformations in Western thought altered not only assumptions about mathematical knowledge but also the curricular and pedagogical orientations associated with those assumptions.

Accordingly, this study examines paradigm changes in Western mathematical thought by tracing the movement across premodern, modern, and postmodern orientations and analyzing their implications for the philosophy of mathematics, curriculum, and pedagogy. Rather than treating these paradigms as sharply separated chronological categories, the study uses them as conceptual frames for identifying continuities, transformations, and tensions in assumptions about reality, knowledge, mathematical certainty, and educational practice. The present study aims to examine the implications of paradigm changes in Western mathematical thought for the philosophy of mathematics and related educational perspectives. Specifically, it seeks:

1. to trace major shifts in Western mathematical thought across premodern, modern, and postmodern paradigmatic orientations; and
2. to analyze how these shifts influenced conceptions of mathematical knowledge and their implications for curriculum and pedagogy.

2. Method

This study employed a qualitative narrative literature review with historical-conceptual analysis and thematic synthesis to examine paradigm changes in Western mathematical thought and their implications for the philosophy of mathematics, curriculum, and pedagogy. A narrative review approach was considered appropriate because the study sought to interpret the historical development and transformation of philosophical ideas rather than to aggregate findings from empirical studies. Relevant scholarly literature was purposively selected according to its relevance to Western philosophical thought, the history and philosophy of mathematics, epistemological and metaphysical perspectives, curriculum theory, and mathematics education. Both foundational works and more recent scholarly sources were considered to connect major historical ideas with subsequent interpretations of mathematical and educational thought.

The analysis proceeded in two interconnected stages. First, the literature was historically organized around three major paradigms: premodernism, modernism, and postmodernism, to trace changes in dominant conceptions of reality, knowledge, and mathematics. Particular attention was given to the transition from cosmic harmony and essentialism in premodern thought, through the mechanistic and rationalist orientation of modernism, to the complexity, contextuality, and plurality associated with postmodern thought. Second, the literature was conceptually synthesized to examine how these paradigm changes influenced the philosophy of mathematics, curriculum, and pedagogy. Within this stage, recurring ideas were organized around the contributions of Descartes and Newton to mathematical and scientific rationality, the curricular and pedagogical consequences of technical rationality, biological and cognitive perspectives associated with Piaget, Bruner's cognitive orientation, and the emergence of nonlinear, transformative, dialogical, and participatory perspectives in curriculum and pedagogy.

The synthesis emphasized continuities, transformations, and conceptual differences across the three paradigms rather than treating individual philosophers or historical periods as isolated accounts. In this way, the review traced how changing epistemological and metaphysical assumptions were associated with changing conceptions of mathematical knowledge and how these changes subsequently influenced curriculum organization and approaches to teaching and learning.

3. Results and Discussion

From the Greek emphasis on cosmic harmony to the mechanistic determinism of the Enlightenment and the chaotic order associated with the contemporary era, each transition fundamentally transformed the status and role of mathematics in the creation of knowledge within society. The major turning points across these three mega-paradigms can be understood through three core areas: cosmology, or the structure of the universe; epistemology, or the nature of knowledge; and metaphysics, or the nature of being (Doll Jr, 1993; Subedi, 2025).

3.1 The Premodern Paradigm: Cosmic Harmony and Essentialism

Premodernism was largely shaped by Greek thought, which viewed the universe as a finite, closed, and harmonious system. In the late Middle Ages, God was regarded as the source of knowledge, while human knowledge was understood as only an infinitesimal part of what God already knew (Osler, 2010). This view was also associated with the broader premodern conception of knowledge (Gnawali, 2024). According to the perspectives attributed to Thomas Aquinas and John Calvin, human relationships and experience could generate knowledge, but such knowledge remained a subset of the knowledge already existing in God (Mansfield & Hall, 2021).

In the premodern era, the geocentric worldview and Euclidean geometry emphasized stability and closed forms as representations of the structure of the universe. Premodern epistemology was largely supernatural, and essential truth was understood as governing reality within a teleological order in which deductive and inductive forms of truth were balanced to fulfill predetermined roles (Doll Jr, 1993). Beliefs and knowledge were also associated with practices such as astrology, some of which were later regarded as superstition. Knowledge was understood as the discovery of divine harmony, and geometry in particular served as a language of eternal order (Dildora & Abdulaziz, 2024). These beliefs gradually weakened as the view of human knowledge as merely a subset of God's knowledge came under increasing scrutiny.

3.2 Modernism: The Mechanistic Revolution

The shift to the modern paradigm was triggered by the scientific and industrial revolutions. The transition from geocentric to heliocentric models, associated with Kepler, Galileo, Copernicus, and others, replaced the idea of cosmic harmony with explanations based on natural laws (Feenberg, 2011; Subedi, 2025). The universe was reconceived as a vast machine, while matter was viewed as spatially extended and governed by universal laws (Hatfield, 2017). In modern epistemology, truth became increasingly associated with objectivity, determinism, and fact-based mathematical proof. Technical rationality emphasized prediction through reason and control within a materialistic worldview (Feenberg, 2011). Rene Descartes was a key transitional figure in the emergence of modernism, challenging aspects of premodern philosophy and placing human thought at the center of existence. In this view, human knowledge was no longer understood simply as a subset of pre-existing divine knowledge; instead, human thought, desire, and existence became important foundations of knowledge. Foundationalism, methodological rigor, disciplinary control, and the assumption of universal truth became central features of this epistemological orientation.

Over time, modern epistemology in the Western world became increasingly linked to naturalism. Within this orientation, matter, energy, time, and space were treated as major sources for understanding reality. Theists and Deists also contributed to the development of modern epistemology. By the twentieth century, theism had increasingly interacted with naturalistic and scientific thought amid major political and intellectual developments, including the rise and fall of fascism and communism (Carson, 2003).

3.3 Postmodern Paradigm: Complexity and Context

The twentieth-century transition toward postmodern thought was influenced by the breakdown of certainty associated with quantum mechanics in physics and Gödel's incompleteness theorems in mathematics. Within this perspective, nature is portrayed as open, fluid, flexible, and subjective (Gnawali, 2024). Truth and reality are viewed as socially constructed and fragmented, challenging the assumption of an ultimate reality grounded in Cartesian dualism. Knowledge is therefore regarded as fallible, contextual, participatory, and subjective rather than universal (Doll Jr, 1993). In contemporary educational settings, rapid instructional and social changes have also shaped the experiences of participants since the Second World War. According to Lyotard & Van Den Abbeele (1984), "postmodernism is an ideological and political marker for referencing a world without stability, where knowledge is constantly reforming." In the literature reviewed here, the postmodern paradigm is described as a closed system that develops from the modernist paradigm and exchanges energy but not matter. It is also associated with transformative approaches to curriculum across disciplines such as biology, chemistry, mathematics, philosophy, and psychology, including the curricular ideas of Bruner, Dewey, Piaget, and Whitehead (Trueit, 2012). Postmodernism does not have a single, transparent meaning; its application varies across fields such as literature, art, communication, architecture, engineering, jurisprudence, and philosophy, and its interpretation may differ from one thinker to another. Key postmodern tenets include the rejection of ultimate reality and absolute truth, the view of knowledge and morality as human constructions, the existence of multiple truths, and the arbitrariness of language (Doll, 1989).

The twentieth century has often been characterized as an age of disillusionment, uncertainty, and anxiety. Werner Heisenberg and other proponents of the Copenhagen interpretation of quantum physics emphasized uncertainty at the microscopic level. In the discussion of Gödel, the foundations of mathematics were also understood as confronting limitations of consistency and completeness in mathematical proof

(Feenberg, 2011). In mathematics, particularly arithmetic, some assumptions underlying basic operations may appear intuitively correct even when they are not formally proven. More broadly, confidence that reason alone would necessarily produce a better, more just, or more moral society was increasingly questioned. J. J. Rousseau contributed to the historical conception of the modern by describing it as a break from established patterns of the past. James Evas similarly associated modernism with novelty, discontinuity, and independence, while Descartes's philosophy divided mind and body (Doll & Broussard, 2002).

In postmodern thought, intellectual inquiry is not grounded in positivistic certainty but in pragmatic doubt and a range of socio-personal and intellectual perspectives. Human experience, local history, and indigenous knowledge are emphasized as important sources of understanding rather than relying exclusively on metanarratives. Dialogic forms of communication can therefore support varied social visions in both policy and instruction by recognizing multiple perspectives and complexity.

3.4 Change in the Philosophy of Mathematics (Descartes' and Newton's Worldviews and Their Impact)

Descartes's search for truth emphasized the role of reason and mental reflection in understanding an ordered world. As cosmological thought changed and the sun assumed a new position within explanations of the universe, nature came to be described in increasingly lawful and regulated terms. This perspective assumed a close relationship between human thought and reality. Rene Descartes introduced analytic geometry by unifying algebra and geometry, thereby transforming mathematical knowledge (Dildora & Abdulaziz, 2024). Hatfield (2017) explained that Descartes established mathematics as a universal method for attaining certainty, arguing that the essence of matter is extension and that the physical world could therefore be described through mathematical equations. In the premodern worldview, the Earth had occupied the center of the universe, while processes such as life, death, reproduction, and growth were commonly interpreted through organic or ecological understandings (Leigh, 2018). With the shift toward modern thought, this organic metaphor was increasingly replaced by a mechanistic one, and the universe came to be conceived as composed of inert particles. The broader shift away from premodernism generated both intellectual uncertainty and fascination with new forms of knowledge. Developments in science and mathematics transformed astronomy, physics, medicine, commerce, and transportation, while also weakening earlier assumptions about natural harmony and order (Dear, 1995). The mechanical metaphor subsequently influenced modern science and mechanistic approaches to curriculum, in which goals were often established prior to instruction. Such approaches could reduce opportunities for meaningful teacher-student interaction in curriculum planning, in contrast to Dewey's view that goals and ends emerge from activity itself. At the same time, the assumption of an orderly universe continued to provide a basis for predictability.

Isaac Newton further elevated the status of mathematics through a mathematized and empirical method. He developed calculus and used mathematical language to describe change and motion (Dildora & Abdulaziz, 2024). Scientific developments from Copernicus to Newton reinforced the expectation that natural phenomena followed stable patterns: the moon would remain in its orbit, winds would continue to blow, clouds would not simply disappear, and fruits would follow regular natural processes. The seventeenth century, however, was also marked by religious, civil, and intellectual turmoil, with the search for stability emerging as a central concern (Parker & Smith, 2005).

Newton's and Descartes's contributions helped restore confidence in an ordered and intelligible world during a period of major paradigmatic change. Descartes's method for "rightly conducting reason" and Newton's "Mathematical Principles of Natural Philosophy" played important roles in this process. Modernism therefore emerged from both a positive vision of rational order and an underlying fear of disorder. Its educational and curricular manifestations likewise reflected a continuing concern with maintaining structure and control.

Through reflection and meditation, Descartes developed a method of analysis that significantly reformulated philosophy. This reformulation altered broader understandings of knowledge across philosophy, science, the social sciences, literature, and theology. Descartes developed a distinctly Protestant philosophical system and adopted a skeptical stance, placing confidence in certain laws of God, mathematical and geometric deduction, and the clarity and distinctness of reflective intelligence. His search for truth was guided by four methodological rules. First, truth should be accepted only when it is self-evident and presented clearly and distinctly to the mind. Second, difficult problems should be divided into smaller and more manageable parts. Third, reasoning should proceed in an orderly sequence. Finally, the entire process should be reviewed to ensure completeness.

Descartes's approach also informed curricular perspectives associated with the modern scientific method and later with the Tyler rationale. Euclidean thought provided a structural foundation for curriculum through four fundamental concerns: purpose, experience, effective organization, and evaluation.

Following Galileo and preceding Locke, Descartes emphasized a distinction between primary qualities, such as size, shape, motion, and position, and secondary qualities, such as color, odor, taste, texture, and sound. He maintained that the relevant order was not created but discovered (Doll, 1993).

Within the premodern paradigm, quantitative scales were limited and systematic measurement was therefore difficult. During the sixteenth and seventeenth centuries, mathematical scientists increasingly organized phenomena along linear scales, making measurement more systematic. For Newton, a symmetrical mathematical order underlay motion and represented a metaphysical abstraction derived from empirical observation. The resulting tension between rational and empirical approaches has continued to influence theoretical and mathematical thought.

3.5 Curricular and Pedagogical Carryovers

Modern curriculum was often organized as a sequence of tasks or bodies of material to be mastered, reflecting linear progression, cause-and-effect relationships, and limited attention to qualitative change over time. Newtonian thinking placed linear sequence at the center of mathematical order, influencing not only calculation but also textbooks, curricula, assignments, and instructional methods. The principle of causality became central to modern science, reinforcing the assumption that the same natural effects should be attributed to the same causes (Doll Jr, 1993; Doll, 1989).

The Newtonian paradigm became so deeply established that development was commonly understood as occurring through sequential and gradual steps. Stability was assumed, and major gaps or breaks in developmental sequences received little attention. This emphasis on gradual progress and linear connectedness was subsequently carried into educational and curriculum theory.

Within the modernist paradigm, curriculum was conceived as a set of autonomous but interconnected units arranged in a linear sequence across grade levels. Learning was often defined in terms of the number of units covered, mastered, and accumulated.

Such an approach makes it difficult to view curriculum as a transformative process involving complex and spontaneous interaction. A transformative curriculum, by contrast, requires curriculum to be understood as more than a series of discrete units; it involves mixed, multivariate, and open-ended experiences (Toland, 2017).

From a postmodern perspective, development is not merely cumulative but qualitatively transformational, emerging as interactions expand and mature over time. Newton's metaphysical conception of individual atoms as the fundamental building blocks of reality also influenced curriculum thinking. In this account, the major curricular carryovers of the modern scientific paradigm are scientific curriculum and technical rationality.

3.6 Influence of Modernism: Technical Rationality

Modernist education is rooted in technical rationality, in which the systematic application of scientific and mathematical principles becomes a central approach to problem solving (Feenberg, 2011). Mathematics instruction is consequently organized around rigid, linear, and efficiency-oriented procedures. Knowledge is treated as universal and relatively unchangeable, while teachers function primarily as transmitters of that knowledge. Algorithm-based problem solving and rote memorization therefore become prominent pedagogical practices designed to ensure control and predictability in learning (Gnawali, 2024).

In nineteenth-century America, changing social needs, particularly in agriculture, drew educational attention toward the personal qualities expected of teachers. As schools expanded amid migration and urbanization, educational systems increasingly adopted principles of scientific management. Herbert Spencer's emphasis on saving time was reflected in curriculum models focused on efficiency and standardization. Harris (2009) identified regularity, punctuality, silence, and industry as cardinal virtues of schooling, qualities intended to produce disciplined workers and students. The learning model underlying this curriculum was associated with what Bruner described as a deficit hypothesis, which assumed that learners, including immigrants and rural populations, entered education with deficiencies that schooling was expected to address.

In mathematics curriculum, Bobbitt shifted attention away from the history and structure of numbers and shapes associated with "new math" toward the practical mathematics of commerce, mining, manufacturing, packing, insurance, and banking. He also advocated a curriculum that focused on the errors students made. The competency-based curriculum movement of the 1970s further framed curriculum as a movement from "form" toward expected performance, using curriculum as a device for expressing and measuring performance deficits.

In the early twentieth century, modernist schooling was characterized by extensive work on scientific curriculum making. According to William Schubert, curriculum development increasingly reflected this scientific orientation, while Charters argued that curriculum should emerge from a matching of ideas with activities. Education and curriculum were deeply grounded in industrial society, where goals and ends could not easily be separated from social activity. Various educational movements ultimately adopted elements of this scientific framework. Hassannejad (2024) strongly emphasized a child-centered approach to curriculum while also calling for a more scientific, specialized, and professional orientation. This discussion incorporated John Dewey's continuing critique of older traditions and his search for alternative approaches.

Tyler synthesized the curricular ideas of several thinkers, including Franklin Bobbitt, W. W. Charters, John Dewey, Boyd Bode, Harold Rugg, and Henry Harap. His synthesis condensed earlier approaches, such as Bobbitt's numerous objectives and

Rugg's eighteen questions, into the more widely known Tyler rationale. Tyler regarded the selection of objectives as the first and essential step in curriculum planning. Within educational philosophy, he also emphasized the selection and assessment of objectives; Kliebard later noted that such assessment may appear value-neutral even though it remains connected to value-laden ends. The contrast between Dewey and Tyler is particularly evident in their views of educational purposes: Dewey saw educational ends as emerging within experiential activity, with learning developing through the process, whereas Tyler viewed educational ends as established prior to experience and learning as intentionally directed toward predetermined outcomes. This contrast becomes important in later critiques associated with postmodern perspectives.

According to Tyler, curriculum goals should reflect both professional and practical work considered essential to contemporary society. Society therefore served not only as a source of needs but also as a context for identifying students' needs and relevant subject matter. The Tyler rationale was expressed in school curricula through the behavioral-objectives movement of the 1960s and the competency-based education movement of the 1970s. Curriculum development followed a linear sequence involving the prior specification of goals, the selection and organization of experiences, and evaluation, thereby reinforcing instrumentalism and formalism. Job analysis also became a source of curriculum planning for identifying the skills, knowledge, and attitudes students were expected to acquire. This scientific tradition in curriculum reflects a practical orientation toward technical and intellectual control of the world, an orientation described as part of the metaphysics of modernist science (Matthews, 2009).

3.7 Influence of Postmodernism: Biological and Cognitive Views

Postmodern pedagogy, strongly influenced by constructivist thought, shifted emphasis from control toward emergence. The discussion contrasts two broad models of modernist thought: physics as a canonical model and forms of social science that often excluded interaction. Mechanical systems do not ordinarily self-organize, compensate, or grow, although developments in artificial intelligence have sought to create systems capable of performing increasingly complex functions.

Biologically oriented models, by contrast, view human beings and learning processes as self-organizing living systems (Kazi & Galanaki, 2020). Interaction is therefore a central feature because the parts of a living system do not operate in isolation. The distinctive characteristics of biological systems make them a potentially more appropriate model for human development than Newtonian physics. Aristotle's thought emphasized premodern balance and harmony rather than organic or living systems in the modern sense. Ideas of transformative and open-ended growth became more prominent with later thinkers such as Darwin and Russell. By the end of the modernist period, biology increasingly examined living organisms as parts of integrated hierarchical systems.

Biological systems possess characteristics that give them a degree of autonomy while preventing their complete reduction to physicochemical laws. These characteristics include organizational complexity, genetic histories of coding, multiple causes, purpose or directionality, and self-organization. A familiar example of hierarchical organization is the relationship between the brain and individual cells, in which the brain functions as an integrated whole.

According to Piaget, assimilation and accommodation occur as learners respond to problems or perturbations (Kazi & Galanaki, 2020). This process can be illustrated through children's difficulties with mathematical operations such as multiplication and division. For example, rather than treating 4×3 only as a memorized fact, a learner may construct the result through repeated groups such as $(2 \times 2, 2 \times 2, 2 \times 2)$ and through

processes of doubling and halving. Four implications for curriculum are emphasized: the biological concept of complexity, the generative nature of thought, a developmental perspective that moves beyond simple accumulation toward transformation, and the need for teachers to recognize more than one level of cognitive operation (Doll, 1993).

At the center of Piaget's theory is the view that knowledge is neither a direct copy of reality nor the simple imposition of a priori forms on reality; rather, it is continually constructed through interaction with the environment. Whereas Darwinian explanations emphasize environmental pressures and chance variation in survival, Piaget regarded purely mechanistic and purposeless explanations as insufficient for understanding cognitive development. Pedagogically, he emphasized a dialogic relationship between the learner and the learning environment, including materials presented by teachers. Applied to cognitive structure, Piaget proposed a model of equilibrium, disequilibrium, and re-equilibration in individual development. Disequilibrium must create sufficient structural disturbance to prompt reorganization and is therefore important to development. Piaget also emphasized action, both as a defining characteristic of the sensorimotor stage and as a quality that continues to shape change across developmental stages (Kazi & Galanaki, 2020).

Piaget's equilibrium model also informed transformative views of curriculum by emphasizing the role of disequilibrium, choice, and purpose in processes of internal restructuring.

3.8 Bruner's Cognitive Revolution

Bruner viewed growth as the individual's increasing ability to represent the world, reality, and culture. He described representation as developing hierarchically, with symbolic representation above iconic representation and iconic representation above enactive representation. Social interaction and reciprocity with others are also central to learning. Curriculum planning and instructional strategies should therefore support student-student and student-teacher dialogue. Bruner emphasized the structure of the subject, the learner's readiness to learn, and the idea that any concept can be taught in an intellectually honest form at any stage of development, thereby supporting discovery-based learning (Pirie & Kieren, 1994; Scott, 2007).

Bruner did not portray children or beginning learners as fully developed thinkers. Instead, he viewed learners as constructors whose constructions improve through the use of tools, social interaction, and recursive thought. In his account, learners can move beyond simply copying the patterns of others when curriculum provides opportunities for experience-based symbolic manipulation, public dialogue, private reflection, and interaction between one's own reflective understanding and that of others. Through these processes, individuals can transform and deepen personal consciousness.

According to Bruner, curriculum should take the form of a spiral in which subjects are revisited over several years at increasing levels of complexity. Subject matter should be introduced in ways that enable students gradually to expand their zone of development and develop their own forms of effective representation. This process is interactive and personal by nature and does not proceed in a purely linear, sequential, cumulative, or stable manner; instead, it develops through multiple perspectives.

3.9 Chaotic Order

Postmodern curriculum development embraces the notion of chaotic order. Rather than following a fixed sequence, it adopts nonlinear approaches to development. Mathematics is viewed not simply as something invented or discovered but as a form of social construction that can accommodate ambiguity and multiple perspectives.

Curriculum should therefore remain flexible and responsive to the social needs and interests of learners and communities (Adha et al., 2021).

Postmodern pedagogy therefore differs from both premodern and modern approaches. It emphasizes dialogical pedagogy, critical and creative thinking, and the construction of mathematical truth (Subedi, 2025).

4. Conclusion

The three mega-paradigms, premodernism, modernism, and postmodernism, emerged in different historical periods and have shaped modern curriculum development, particularly in mathematics education. The evolution of mathematical thought can be understood as a movement from an emphasis on eternal cosmic order, through a mechanistic conception of the world, toward more flexible, complex, and socially constructed perspectives. In premodernism, God was regarded as the ultimate source of knowledge, and human knowledge was understood as only an infinitesimal part of divine knowledge. Premodern epistemology was therefore largely supernatural and framed knowledge through a divinely ordered cosmos. Modern epistemology shifted attention toward human reason and provided tools for technical progress through mechanistic approaches to knowledge and learning. In the early seventeenth century, Rene Descartes became an important transitional figure through his emphasis on rational certainty and foundational philosophical claims. Modernism was increasingly human-centered: scientific truths were treated as certain and objective, rationality became a primary means of organizing knowledge, and explanations based on nature increasingly challenged religious authority. Postmodernism emerged after the Second World War and extended into contemporary thought. In the account reviewed here, it is described as developing from modernism and through the language of systems and energy exchange. It also emphasizes pluralism, contextuality, and the absence of a single ultimate reality. Knowledge is therefore neither eternal nor universally fixed. Postmodernism offers a different social, intellectual, and personal vision, emphasizing more holistic and participatory frameworks while recognizing the limitations of formal systems of learning.

From a modernist perspective, curriculum is organized into autonomous but interconnected units, typically arranged in sequence across grade levels. From a postmodern perspective, however, development is not merely cumulative but qualitatively transformational as interactions expand and mature over time. The history of mathematics likewise shows that mathematical concepts, proofs, and standards of proof continue to evolve. Contemporary humanist, relativist, social-constructivist, and fallibilist philosophies treat mathematical knowledge, curriculum, and pedagogy as open to revision and reinterpretation. Although some educational concepts continue to reflect closed, stable, and non-exchange models, contemporary mathematics education increasingly emphasizes transformative, self-organizing, and abstract forms of knowledge.

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