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Designing interactive mathematics learning through social constructivism: Pedagogical principles and classroom implementation

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Abstract---*This article examines the design of interactive mathematics learning environments from a social constructivist perspective and proposes pedagogical directions for classroom implementation in secondary education. Drawing on social constructivism and Vygotskian sociocultural theory, the study conceptualizes mathematics learning as a process in which learners construct and refine mathematical meaning through individual exploration, social interaction, mathematical language, argumentation, and teacher support. Four interrelated dimensions of a social constructivist mathematics classroom are identified: cognitively productive mathematical tasks, learner-generated mathematical ideas, dialogic interaction, and adaptive scaffolding. Based on these dimensions, the article proposes five pedagogical principles and a five-phase instructional model comprising problem engagement, individual sense-making, collaborative negotiation, collective mathematical construction, and transfer and reflection. The proposed model is illustrated through the teaching of quadratic functions at the upper secondary level, where students investigate relationships among algebraic expressions, tables, and graphical representations before collectively constructing key mathematical properties. The analysis suggests that social constructivist mathematics teaching should not be understood simply as increasing group work or reducing direct instruction. Rather, it requires carefully designed tasks, purposeful classroom discourse, differentiated support, and teacher-guided formalization of mathematical knowledge. The framework developed in this article provides a theoretical and pedagogical basis for designing mathematics lessons that promote active participation, mathematical communication, reasoning, and deeper conceptual understanding.*
Keywords---*social constructivism, mathematics education, mathematical discourse, scaffolding, classroom interaction, secondary education.*

Introduction

Contemporary mathematics education increasingly emphasizes the development of students' mathematical reasoning, problem-solving ability, communication, collaboration, and capacity to apply knowledge in unfamiliar situations. These expectations require a movement beyond instructional models in which mathematical definitions, rules, and procedures are primarily presented by the teacher and subsequently reproduced by students. Instead, mathematics classrooms need to provide opportunities for learners to explore problems, generate mathematical ideas, communicate their reasoning, compare alternative approaches, and revise their understanding through interaction.

Social constructivism provides a useful theoretical perspective for such a transformation. From a social constructivist viewpoint, learning is not simply an individual process of receiving information but a process in which meaning is actively developed through participation in socially and culturally situated activities. Palincsar (1998) describes social constructivist perspectives as emphasizing the interdependence between individual cognition and social processes, particularly dialogue, interaction, and participation in shared activities. Mathematical understanding, therefore, develops not only through what a learner thinks individually but also through how mathematical ideas are communicated, questioned, negotiated, and reconstructed within a learning community.

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This perspective is particularly relevant to mathematics education. Mathematical knowledge taught in schools consists not only of concepts, formulas, and algorithms but also of forms of representation, explanation, justification, and reasoning. Ernest (1994) argues that mathematical knowledge and mathematical learning should be considered within social and communicative contexts. A mathematics classroom can consequently be viewed as a community in which learners participate in producing and evaluating mathematical meaning rather than merely receiving finished mathematical knowledge.

Research on constructivist mathematics teaching has highlighted the importance of active learner participation. Vasuki et al. (2016) indicate that constructivist approaches can encourage learners to take a more active role in the mathematics classroom, although successful implementation depends on appropriate instructional design and teacher facilitation. Thu & Thu (2023), in applying constructivist theory to primary mathematics teaching, similarly demonstrate the possibility of organizing learning situations in which students participate in discovering and developing mathematical knowledge.

The sociocultural theory associated with Vygotsky further explains why interaction and instructional support are central to learning. From this perspective, cognitive development is mediated through social interaction, language, cultural tools, and participation with more capable others. Concepts such as the Zone of Proximal Development suggest that students may be able to accomplish more complex cognitive activities with appropriate assistance than they can independently. Wibowo et al. (2025) emphasize the relevance of Vygotskian constructivism to differentiated learning because learners' needs and levels of independence differ, requiring flexible forms of instructional support.

In mathematics classrooms, language and interaction play a particularly important role because students need to explain relationships, interpret symbolic representations, justify conclusions, and respond to alternative arguments. Luong (2022) highlights the significance of the concepts of community and social interaction in mathematics teaching for developing mathematical communication competence. Mathematical discourse can therefore function simultaneously as a means of communication and as a cognitive tool through which learners organize and refine their thinking.

At the same time, social constructivist teaching should not be reduced to putting students into groups, allowing unrestricted discovery, or minimizing the teacher's role. Effective learning depends on the quality of mathematical tasks, the forms of interaction established in the classroom, the questions used by teachers, and the process through which emerging student ideas are connected to accepted mathematical knowledge. Mishra (2023) stresses that social constructivist pedagogical models require meaningful learner participation combined with appropriate instructional mediation. More recent studies have also demonstrated that constructivist principles continue to be relevant in pedagogical models involving project-based learning, computational thinking, and technology-enhanced education (Al-Kamzari & Alias, 2025; Angraini et al., 2024; Gupta et al., 2024).

These considerations suggest the need to move from general statements about social constructivism toward a more operational framework for mathematics classroom design. Teachers require clearer guidance concerning what kinds of mathematical tasks should be selected, how individual and collaborative activities should be connected, how classroom discussion can contribute to mathematical knowledge construction, and when and how instructional support should be provided (Schoenherr et al., 2024).

Accordingly, this article aims to: (1) clarify the theoretical foundations of interactive mathematics learning from a social constructivist perspective; (2) identify key dimensions and pedagogical principles for designing social constructivist mathematics classrooms; (3) propose a five-phase instructional model for secondary mathematics teaching; and (4) illustrate the model through the teaching of quadratic functions. The article is conceptual in nature and seeks to provide a pedagogical framework that can support lesson design and future empirical research.

Research Methodology

This study employed a qualitative conceptual research design to examine the theoretical foundations of social constructivism and to develop a pedagogical framework for interactive mathematics teaching. The study did not involve experimental intervention or the collection of primary data from teachers or students. Instead, it focused on the analysis, comparison, and synthesis of theoretical and empirical literature relevant to social constructivism, mathematics education, classroom interaction, scaffolding, and learner-centered instructional design (Legesse et al., 2020).

The research process consisted of three main stages. First, the study reviewed the theoretical literature on social constructivism, with particular attention to the role of social interaction, language, the Zone of Proximal Development, learner participation, and instructional support. Foundational perspectives were drawn primarily from the works of Ernest (1994) and Palincsar (1998), while more recent studies were used to clarify the pedagogical implications of constructivist and sociocultural perspectives in contemporary educational settings (Mishra, 2023; Wibowo et al., 2025).

Second, the selected literature was analyzed thematically to identify recurring principles relevant to mathematics teaching. The analysis focused on five areas: the role of prior knowledge in mathematical learning; the design of cognitively meaningful mathematical tasks; interaction and mathematical communication; teacher scaffolding; and the process through which informal learner-generated ideas are developed into formal mathematical knowledge. Studies relating constructivism to mathematics teaching, mathematical communication, computational thinking, differentiated learning, project-based learning, and technology-supported education were used to examine how these principles have been interpreted and applied in different contexts (Vasuki et al., 2016; Luong, 2022; Thu & Thu, 2023; Angraini et al., 2024; Al-Kamzari & Alias, 2025).

Third, theoretical synthesis was used to construct an instructional framework for secondary mathematics education. Concepts and pedagogical features identified across the reviewed studies were compared and reorganized into four interrelated dimensions of a social constructivist mathematics learning environment and five pedagogical principles. These principles were subsequently operationalized into a five-phase instructional model consisting of problem engagement, individual sense-making, collaborative negotiation, collective mathematical construction, and transfer and reflection.

To examine the practical coherence of the proposed framework, the five-phase model was applied analytically to the teaching of quadratic functions at the upper secondary level. This illustration was not intended as empirical evidence of effectiveness but as a pedagogical example demonstrating how the theoretical principles could be translated into a sequence of classroom activities. The example was selected because quadratic functions allow students to work with multiple mathematical representations, including algebraic expressions, numerical tables, and graphs, thereby providing opportunities for individual exploration, comparison of strategies, mathematical discussion, and generalization.

The analysis was interpretive and theory-driven. The selected studies were not treated as a systematic review dataset for quantitative aggregation; rather, they served as conceptual sources for identifying, comparing, and synthesizing pedagogically relevant ideas. The credibility of the proposed framework was strengthened by maintaining consistency between the theoretical constructs identified in the literature and the instructional components derived from them. Accordingly, the proposed model should be understood as a theoretically grounded pedagogical framework that requires further empirical validation in different mathematics classroom contexts (Pakarinen et al., 2014).

Social Constructivism and Interactive Mathematics Learning

Learning as socially mediated knowledge construction

Social constructivism views learning as an active and socially mediated process. Knowledge is not transferred intact from the teacher's mind to the learner's mind. Learners interpret new information through existing knowledge and experience while simultaneously developing understanding through interaction with other people and participation in social practices.

Palincsar (1998) emphasizes that social constructivist perspectives challenge any strict separation between individual cognition and the social context of learning. The learner's thinking develops through interactions in which ideas are articulated, questioned, supported, rejected, modified, and reconstructed. This does not mean that individual thinking disappears. Rather, individual cognition and social interaction continually influence one another.

From a Vygotskian perspective, language serves an important mediational function. Learners use language not only to communicate finished ideas but also to formulate and reorganize thought. Explaining a solution to a peer, responding to a question, identifying a contradiction, or attempting to justify a conjecture may therefore contribute directly to cognitive development.

The Zone of Proximal Development further illustrates the relationship between learning and social support. Learners may initially be unable to complete a task independently but may succeed when they receive strategically selected assistance. This assistance can take the form of teacher questions, visual representations, worked examples, peer explanations, hints, or partial structures. As competence develops, such support can gradually be reduced.

Wibowo et al. (2025) connect this theoretical principle to differentiated learning. Since students differ in their prior understanding, learning pace, strategies, and need for support, the same form or level of assistance is unlikely to be equally appropriate for all learners. Social constructivist teaching consequently requires adaptive rather than uniform support.

The social construction of mathematical meaning

The relevance of social constructivism to mathematics education lies partly like mathematical learning itself. Students do not develop mathematical competence simply by memorizing symbolic statements. They must learn how representations relate to one another, why mathematical procedures work, under which conditions conclusions are valid, and how a mathematical claim can be justified.

Ernest (1994) emphasizes the social dimension of mathematical knowledge and mathematics education. From this perspective, school mathematics involves participation in particular practices of representing, explaining, arguing, defining, and validating mathematical ideas. Learning mathematics therefore requires students to become increasingly capable participants in these practices.

Consider, for example, a student learning the concept of a function. Knowing the formal definition alone is insufficient. The student must make connections among numerical tables, graphs, algebraic expressions, mappings, and contextual situations. Different students may initially develop different interpretations of these representations. Classroom interaction creates opportunities for such interpretations to become visible and available for comparison.

Accordingly, social interaction has an epistemic function in mathematics learning. When two students obtain different answers, use different representations, or propose different generalizations, the resulting disagreement can become a productive source of mathematical reasoning. Students may need to test examples, construct counterexamples, examine assumptions, or justify why one method is more general than another.

Luong (2022) similarly emphasizes that community and social interaction can support the development of learners' mathematical communication. Such communication involves more than using mathematical terminology correctly. It includes expressing reasoning coherently, interpreting the reasoning of others, using representations to support explanations, and responding to mathematical arguments.

A social constructivist mathematics classroom can therefore be understood as a learning community in which individual ideas are made public, collectively examined, and gradually connected to mathematically accepted concepts and relationships.

Reconceptualizing the roles of students and teachers

Social constructivism leads to a significant reconsideration of classroom roles. Students are expected to contribute intellectually to the learning process rather than function primarily as recipients of teacher explanations. They investigate, predict, represent, question, explain, compare, and justify.

This active participation does not imply that learners must independently rediscover all mathematical knowledge. Completely unguided discovery may create unnecessary cognitive difficulties or leave misconceptions unresolved. Instead, the teacher designs conditions under which productive student thinking can occur.

The teacher's role can therefore be characterized through several functions: designing mathematically productive tasks; activating relevant prior knowledge; observing student reasoning; selecting ideas for discussion; posing questions that extend thinking; providing appropriate scaffolding; connecting different representations; and eventually formalizing the mathematical knowledge emerging from classroom activity.

Vasuki et al. (2016) note that constructivist mathematics classrooms offer important possibilities but also present practical challenges. Teachers must anticipate different student approaches and manage classroom interaction without allowing mathematical goals to become unclear. In this sense, social constructivist teaching may require greater pedagogical orchestration rather than less teacher expertise. The relationship can be summarized as a shift from teacher transmission and student reproduction toward teacher design and mediation combined with student exploration and knowledge construction.

Dimensions of a Social Constructivist Mathematics Learning Environment

Cognitively productive mathematical tasks

The first dimension concerns the mathematical task. Interaction by itself does not guarantee meaningful learning. Students may work collaboratively while completing routine exercises that require little reasoning. For social constructivist learning to occur, tasks need to create opportunities for interpretation, decision making, conjecture, comparison, and justification.

A productive task should connect with students' existing knowledge while containing an element that cannot be resolved through mechanical recall alone. It may involve a pattern to be generalized, an unfamiliar problem, contrasting solutions, multiple representations, incomplete information, or a statement that students must evaluate.

Such a task creates an intellectual reason for interaction. Students communicate not simply because the teacher requires group work but because there is something mathematically meaningful to determine, compare, or justify.

This idea is consistent with constructivist-oriented pedagogical models in which learners actively engage with authentic or intellectually meaningful problems (Mishra, 2023). Project-based approaches also demonstrate how learning can be organized around sustained problem solving and learner participation (Al-Kamzari & Alias, 2025).

Learner-generated mathematical ideas

The second dimension is the visibility of student thinking. If teachers immediately present a standard method, there may be little reason for students to produce their own mathematical representations or strategies.

A social constructivist environment deliberately creates space for learner-generated ideas. These may include correct solutions, incomplete strategies, alternative representations, intuitive conjectures, and misconceptions. From a pedagogical perspective, all of these can provide useful resources for learning.

Errors are especially significant. Rather than being treated only as outcomes that should be corrected, errors can become objects of collective analysis. Students can examine where a reasoning process becomes invalid, identify a counterexample, or compare an incorrect generalization with a valid one. Such processes help transform individual mathematical thinking into material for collective knowledge construction.

Dialogic mathematical interaction

The third dimension concerns the quality of classroom discourse. Social constructivism requires more than students talking to one another. The interaction must involve mathematical substance.

Productive mathematical dialogue may involve explaining why a procedure works, comparing representations, evaluating evidence, challenging a generalization, responding to an alternative solution, or constructing a shared argument.

Teachers can encourage such interaction through questions such as: Why do you think this relationship is true? Can you represent the same idea in another way? How is your method different from the other group's method? Does this conclusion work for every case? Can you construct an example for which this rule fails? What evidence supports your conclusion?

Such questions position mathematical reasoning rather than answer production as the central object of classroom interaction.

Luong (2022) suggests that social interaction in mathematics learning can contribute directly to learners' mathematical communication competence. Through repeated participation in explanation and argumentation, students gradually learn how mathematical claims are communicated and justified.

Adaptive scaffolding and mathematical formalization

The fourth dimension concerns support and formalization. Social constructivist learning requires teachers to maintain a balance between learner independence and pedagogical guidance.

Scaffolding should respond to the learner's current state. When a student is close to making progress, a brief prompt may be sufficient. When a group lacks a crucial representation, the teacher may introduce a diagram, table, or strategically selected example. When several learners share a misconception, a whole-class question may be appropriate.

Wibowo et al. (2025) highlight the relevance of Vygotskian theory to responding to learner differences. Adaptive scaffolding is consistent with this perspective because students do not necessarily require the same instructional intervention at the same moment.

Equally important is the process by which informal or learner-generated ideas are connected to formal mathematical knowledge. Classroom discussion cannot remain indefinitely at the level of personal strategies. The teacher ultimately needs to identify mathematically important relationships, introduce accepted notation and terminology, clarify conditions, and establish generalized conclusions. Thus, social constructivist teaching combines learner-generated meaning with teacher-guided formalization.

Pedagogical Principles for Interactive Mathematics Teaching

First, teaching should begin with learners' existing mathematical resources. New knowledge needs to connect with prior understanding, experience, representations, and strategies. Teachers should therefore identify what students already know and use initial tasks to activate this knowledge.

Second, instruction should create an intellectual need for new mathematical knowledge. Students should encounter a problem, contradiction, pattern, or unfamiliar situation that cannot be resolved simply through mechanical recall. New concepts and procedures then become meaningful because they respond to a genuine mathematical need.

Third, student reasoning should be made visible and discussable. Learners need opportunities to express their mathematical thinking through oral explanations, written work, diagrams, symbols, tables, and graphs. Once made visible, these ideas can be compared, questioned, and refined.

Fourth, interaction should be used to develop mathematical reasoning rather than merely increase classroom participation. Pair work and group work should require students to explain, justify, challenge, compare, or reach agreement based on mathematical evidence.

Fifth, teachers should provide adaptive support and progressively formalize mathematical knowledge. Support needs to be timely and flexible, while the final stage of learning should connect students' informal ideas to precise mathematical concepts, notation, properties, and procedures.

These principles can be summarized through the following pedagogical logic: prior understanding → productive challenge → individual ideas → social negotiation → scaffolded formalization.

A Five-Phase Pedagogical Model

Phase 1: Problem engagement

The teacher introduces a mathematical situation that activates relevant prior knowledge while raising a question students need to investigate.

The task should be accessible enough for students to begin thinking without first receiving a complete explanation of the target knowledge. At the same time, it should contain sufficient depth to generate different approaches or representations.

Students may initially be asked to predict, estimate, identify patterns, or explain what they notice. These responses allow the teacher to identify prior understanding and possible misconceptions.

Phase 2: Individual sense-making

Students first work independently. This stage is important because immediate group discussion may cause less confident learners to adopt the ideas of others without developing their own initial interpretation.

Students may calculate examples, draw diagrams, create tables, sketch graphs, or formulate conjectures. The teacher observes the strategies that emerge and identifies ideas that may later be useful for whole-class discussion.

Phase 3: Collaborative negotiation

Students then work in pairs or small groups to compare their initial ideas.

The purpose is not simply to produce one group answer. Learners are expected to explain their reasoning, identify differences among approaches, examine contradictions, and determine which claims are mathematically justified. When groups encounter difficulties, the teacher provides support through questions, examples, or representations rather than immediately presenting the complete solution.

Phase 4: Collective mathematical construction

Selected student ideas are discussed by the whole class. The teacher can sequence contributions from intuitive or specific approaches toward more general and formal representations.

Correct and incorrect ideas may both be used when they have pedagogical value. Students analyze the reasoning behind each approach and identify mathematical relationships that remain valid across different cases.

At an appropriate point, the teacher formalizes the emerging knowledge through standard terminology, symbols, definitions, properties, and general procedures.

Phase 5: Transfer and reflection

Students apply the newly constructed knowledge to a different mathematical situation. The new task should require some degree of adaptation rather than simple repetition.

Reflection can also be included through questions such as: What changed in your understanding? Which representation helped you most? Why does the general rule work? What mistake might occur when applying this result?

This stage allows learners to consolidate knowledge and recognize the reasoning processes involved in its construction.

8. Illustration: Constructing the Properties of Quadratic Functions

The proposed model can be illustrated through an introductory lesson on quadratic functions at the upper secondary level.

Instead of beginning by giving students formulas for the vertex and axis of symmetry, the teacher presents three functions:

$f(x) = x^2$

$g(x) = x^2 - 4x + 3$

$h(x) = x^2 + 4x + 3$

Students are asked to predict similarities and differences among the graphs, identify where each graph may reach its minimum value, and consider how the coefficients of the expressions may affect the horizontal position of the graphs.

During the individual sense-making phase, students may construct tables of values or transform the algebraic expressions.

For example, for $g(x) = x^2 - 4x + 3$, some students may calculate:

$g(0) = 3$, $g(1) = 0$, $g(2) = -1$, $g(3) = 0$, $g(4) = 3$.

From the symmetry of these values, they may conjecture that the minimum point is $(2, -1)$.

Other students may rewrite the expression as: $g(x) = (x - 2)^2 - 1$, and identify the minimum point directly.

Similarly, $h(x) = x^2 + 4x + 3 = (x + 2)^2 - 1$, which suggests a minimum point at $(-2, -1)$.

During collaborative negotiation, students compare numerical, graphical, and algebraic approaches. The teacher asks questions such as: Why do equal function values occur at points equally distant from $x = 2$? What information does the form $(x - 2)^2 - 1$ reveal more clearly than $x^2 - 4x + 3$? Why does replacing $x - 2$ with $x + 2$ move the graph in the opposite horizontal direction?

These questions encourage students to connect algebraic and graphical representations.

During whole-class discussion, the teacher guides students toward the general form: $y = a(x - p)^2 + q$.

Students observe that when $a > 0$, the expression $(x - p)^2$ is always non-negative. Therefore, the minimum value of the function occurs when $x = p$, and the vertex is (p, q).

The teacher then connects this observation to the general quadratic function: $y = ax^2 + bx + c$.

By completing the square, students can be guided to recognize that the axis of symmetry is:

$x = -b/(2a)$.

The important point is that this formula is introduced as a generalization of relationships students have already explored, rather than as an isolated rule to memorize.

In the transfer phase, students investigate a new function: $y = -2x^2 + 8x - 5$.

They are asked to determine whether the parabola opens upward or downward, identify its axis of symmetry and vertex, determine its maximum or minimum value, and justify the result using at least two approaches.

This final requirement encourages students to connect procedures with mathematical reasoning.

The illustration demonstrates how a lesson can move from an initial mathematical problem through individual exploration, interaction, scaffolding, collective reasoning, and formalization. The mathematical knowledge is not left entirely for students to discover independently, nor is it presented fully in advance. Instead, it is progressively constructed through a combination of learner activity and teacher mediation.

Discussion

The proposed framework highlights several important characteristics of social constructivist mathematics teaching.

First, meaningful interaction depends on meaningful mathematical content. Group work alone does not guarantee deep learning. If students only divide routine exercises among group members, interaction may have little influence on conceptual understanding. Social constructivist teaching therefore requires tasks that create genuine reasons for students to discuss, compare, and justify mathematical ideas.

Second, individual exploration and collaborative learning should complement one another. Social constructivism does not imply that all learning must occur collectively. Students need time to develop initial interpretations before engaging with the ideas of others. The movement between individual and social activity supports both independence and collaborative knowledge construction.

Third, mathematical discourse needs to be deliberately developed. Students should learn not only to provide answers but also to explain why a result is valid, evaluate alternative methods, and respond to mathematical arguments. Luong (2022) emphasizes the contribution of social interaction to mathematical communication competence, which supports this view.

Fourth, scaffolding needs to be adaptive. Students differ in prior knowledge, learning pace, and ability to solve problems independently. Wibowo et al. (2025) show the relevance of Vygotskian constructivism to differentiated learning, suggesting that instructional support should vary according to learners' needs.

Fifth, the teacher remains indispensable. A common misunderstanding is that constructivist teaching requires teachers to minimize explanation. In fact, teacher explanation remains important, but its timing and purpose change. Rather than necessarily presenting all knowledge before student activity, teachers may use explanation to connect, clarify, generalize, and formalize ideas after students have developed an intellectual basis for understanding them.

The framework also has implications for technology-supported learning. Angraini et al. (2024) demonstrate the relevance of constructivist theory to computational thinking, while Gupta et al. (2024) show that emerging technologies such as generative artificial intelligence are increasingly becoming part of educational environments. Digital tools can help students generate examples, visualize mathematical relationships, test conjectures, and compare representations.

However, technology does not automatically create constructivist learning. A digital platform may simply reproduce teacher-centered instruction in another format. Technology becomes pedagogically meaningful when it supports exploration, interaction, reasoning, representation, and reflection.

Similar considerations apply to project-based learning. Al-Kamzari & Alias (2025) identify theoretical foundations and design principles for project-based learning in secondary physics. Although their study focuses on a different subject, its emphasis on meaningful tasks, learner participation, collaboration, and teacher guidance is also relevant to mathematics education.

Thus, the framework proposed in this article should not be interpreted as a single instructional method. Problem-based learning, cooperative learning, guided discovery, mathematical investigation, project-based learning, and technology-enhanced learning may all be compatible with social constructivism when they promote meaningful mathematical construction and interaction.

Pedagogical Implications

Several pedagogical implications can be drawn from the proposed framework.

First, lesson planning should focus not only on what content the teacher will explain but also on what students will be asked to think about before formal instruction. Teachers should anticipate possible strategies, misconceptions, and differences in representation that may be useful for discussion.

Second, teacher questioning should move beyond checking answers. Questions such as "Why?", "How do you know?", "Is this always true?", and "Can you represent the idea differently?" can transform classroom exchanges into mathematical dialogue.

Third, errors should be treated as potential learning resources. A mathematically significant error can provide an opportunity for students to identify conditions, test counterexamples, and refine their understanding.

Fourth, classroom organization should serve cognitive purposes. Individual work, pair discussion, small-group collaboration, and whole-class interaction should be selected according to what type of mathematical thinking each form can support.

Fifth, assessment should attend not only to final answers but also to students' explanations, representations, arguments, and ability to respond to alternative mathematical ideas.

Finally, teacher professional development should include the design and orchestration of mathematical discourse. Social constructivist teaching requires teachers to respond flexibly to learner-generated ideas while maintaining clear mathematical objectives. This demands substantial pedagogical expertise.

Conclusion

Social constructivism provides a meaningful theoretical basis for designing mathematics classrooms in which learners actively participate in the development of mathematical understanding. From this perspective, mathematics learning emerges through an interaction among prior knowledge, individual exploration, language, social participation, teacher mediation, and progressive formalization.

This article has identified four dimensions of an interactive social constructivist mathematics environment: cognitively productive mathematical tasks, learner-generated mathematical ideas, dialogic mathematical interaction, and adaptive scaffolding combined with mathematical formalization. From these dimensions, five pedagogical principles were formulated and operationalized through a five-phase model consisting of problem engagement, individual sense-making, collaborative negotiation, collective mathematical construction, and transfer and reflection.

The illustration involving quadratic functions demonstrates how the model can shift the introduction of mathematical knowledge from immediate teacher presentation toward a process in which students encounter a meaningful problem, develop preliminary representations, compare different approaches, and participate in the construction and formalization of general mathematical relationships.

Social constructivist mathematics teaching should therefore not be equated with unrestricted discovery or with the simple use of cooperative groups. Its effectiveness depends on a deliberate relationship among task design, individual thinking, interaction, mathematical discourse, adaptive support, and teacher-guided formalization. The teacher remains central, but the nature of that role changes from primarily transmitting completed knowledge to designing and mediating conditions in which mathematical knowledge becomes meaningful to learners.

The framework presented in this article is conceptual and requires further empirical examination. Future studies could implement the proposed model across different mathematical topics, grade levels, and learner groups; investigate changes in mathematical reasoning and communication; and examine how digital technologies and artificial intelligence can support socially mediated mathematical learning without replacing students' own reasoning.

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