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Problem Situations as Epistemological Foundations: A Comparative Analysis of Chinese Curriculum Standards and International Frameworks

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Abstract

The concept of "problem situation" occupies a central position in Chinese mathematics curriculum standards. Rather than treating situations as mere decorative backgrounds for mathematical problems, the Chinese curriculum imbues them with a generative epistemological role, serving as the soil from which mathematical knowledge grows. This paper examines this distinctive conception through comparative analysis with four major international theoretical traditions: PISA's mathematical literacy framework, Brousseau's Theory of Didactical Situations, Freudenthal's Realistic Mathematics Education, and Lave and Wenger's theory of situated learning. The analysis reveals that the Chinese curriculum's treatment of problem situations is unique in simultaneously positioning them as cognitive activities, instructional goals, and instructional approaches. This triple function resonates with but also diverges from international perspectives. Furthermore, the Chinese curriculum distinguishes three types of situations (real-world, mathematical, and scientific), each of which entails distinct epistemological demands: mathematization for real-world situations, formalization for mathematical situations, and modeling for scientific situations. The paper traces how this three-fold typology develops across educational stages from elementary to senior high school and argues that the Chinese curriculum's conception of problem situations offers productive contributions to international mathematics education discourse.

I. INTRODUCTION

The role of context in mathematics education has been debated for decades, with different theoretical traditions offering competing visions of how situations should relate to mathematical learning. Should mathematical problems be embedded in real-world contexts to make them meaningful and motivating? Should situations be carefully designed didactical environments that provoke specific mathematical reasoning? Or should situations be understood as the very ground from which mathematical knowledge emerges? These questions are not merely pedagogical; they reflect deep epistemological commitments about the nature of mathematics and its relationship to the world. At their core, they concern whether situations serve as vehicles for delivering pre-formed mathematical content, or whether they play a more fundamental role in the genesis of mathematical thinking. These questions lie at the heart of curriculum design and have received markedly different answers across educational traditions.

Research has long recognized that Chinese mathematics education possesses distinctive features shaped by its cultural and institutional context (Ding, Wu, Liu, & Cai, 2022; Leung, 2001). Within this distinctive tradition, the concept of "problem situation" (问题情境) has undergone significant development. The 2022 revision of the Compulsory Education Mathematics Curriculum Standards (Ministry of Education, 2022) places problem situations at the center of both curriculum content and pedagogical design. The standards explicitly require that students learn to "discover and pose problems, analyze problems, and solve problems" within authentic situations, and the notion of problem situation permeates virtually every aspect of the curriculum document. As Cai, Wang, and Xie (2025) observed in their analysis of the 2022 standards, the concept of problem posing appears more than 80 times across the document, functioning simultaneously as a cognitive activity, a curricular goal, and a pedagogical approach. This triple function is unusual and warrants closer examination.

The Chinese curriculum standards classify problem situations into three broad types: real-world situations (现实情境), mathematical situations (数学情境), and scientific situations (科学情境). Each type is understood to play a distinct role in students' mathematical development. Real-world situations connect mathematics to everyday life and social contexts; mathematical situations involve problems internal to mathematics itself, such as patterns, conjectures, or logical challenges; and scientific situations draw on the natural sciences as contexts for mathematical reasoning. What is notable, and what distinguishes the Chinese approach from most international frameworks, is that these three types are not merely presented as alternative "flavors" of contextualization, but are implicitly treated as requiring different cognitive processes and serving different epistemological functions.

This paper argues that the Chinese curriculum's conception of problem situations embodies a distinctive epistemological stance: situations are not decorative backgrounds ("wrapping paper") for pre-existing mathematical knowledge, but rather the generative ground from which mathematical understanding emerges. We develop this argument through comparative analysis with four influential international frameworks that have shaped how the global mathematics education community thinks about the relationship between situations and problems: the PISA mathematical literacy framework (OECD, 2023), Brousseau's (1997) Theory of Didactical Situations, Freudenthal's (1991) Realistic Mathematics Education, and Lave and Wenger's (1991) theory of situated learning. Each of these traditions offers valuable insights into how situations mediate mathematical learning, yet none fully captures the integrated, multi-layered conception found in the Chinese curriculum standards.

The paper proceeds as follows. Section 2 examines four international theoretical traditions regarding situations and problems. Section 3 analyzes the Chinese curriculum's conception of problem situations, focusing on the epistemological role each type of situation plays. Section 4 presents the comparative analysis, identifying convergences and divergences across the four perspectives. Section 5 traces the cross-stage development of problem situations across the Chinese curriculum from elementary to senior high school. Section 6 discusses implications for international mathematics education, and Section 7 concludes.

II. INTERNATIONAL THEORETICAL FRAMEWORKS ON SITUATIONS AND PROBLEMS

2.1 PISA: Situations as Instruments for Assessing Mathematical Literacy

The Programme for International Student Assessment (PISA), administered by the Organisation for Economic

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Co-operation and Development (OECD), has exerted considerable influence on how educational systems worldwide conceptualize the relationship between mathematical knowledge and real-world contexts. In the PISA framework, mathematical literacy is defined as a person's capacity to "formulate, employ, and interpret mathematics in a variety of contexts" (OECD, 2023). The emphasis on "various contexts" is central: PISA classifies problems according to four situational categories: personal, occupational, societal, and scientific, and assesses how well students can navigate the full mathematical modelling cycle within each.

The PISA framework conceptualizes the situation as a container for mathematical tasks. The process of engaging with a problem involves three key steps: formulating a real-world problem mathematically, employing mathematical concepts and procedures to arrive at a solution, and interpreting the mathematical result back in terms of the original situation. The situation here is instrumental: it provides the "real-world" setting that motivates the problem and grounds the interpretation of results. Mathematical knowledge itself is understood to exist independently of the situation; the situation serves as the stage on which mathematical literacy is displayed and assessed.

This instrumental conception has undeniable strengths. It provides a clear, operationalizable framework for large-scale assessment, and it emphasizes that mathematical competence involves more than procedural fluency; it requires the ability to move between mathematical and extra-mathematical worlds. However, it also implies a somewhat one-directional relationship: mathematics exists first, and situations are then deployed to test whether students can apply it. The situation does not generate new mathematics; it tests pre-existing competence.

PISA's framework has been influential in shaping curriculum reforms worldwide, including in China, where the emphasis on mathematical modelling and real-world application in the 2022 curriculum standards shows clear resonance with PISA's orientation. Yet, as we shall see, the Chinese curriculum goes beyond PISA's instrumental view in attributing a more generative role to situations.

An important limitation of the PISA approach for curriculum purposes is its treatment of situations as essentially interchangeable assessment contexts. A personal situation (e.g., comparing mobile phone plans) and a scientific situation (e.g., modeling population growth) are treated as different "wrappers" for the same underlying mathematical competence. This works well for large-scale assessment, where comparability across contexts is essential. But for curriculum design and classroom teaching, the assumption that situations are interchangeable is problematic: a student who can solve a mathematics problem embedded in a personal context may struggle with the same problem in a scientific context, not because of lacking mathematical competence, but because of difficulty in understanding or mathematizing the specific type of situation. The Chinese curriculum's differentiation of situation types can be understood as a response to this limitation.

2.2 Brousseau: Situations as Structured Systems for Knowledge Genesis

Guy Brousseau's (1997) Theory of Didactical Situations (TDS), developed over several decades beginning in the 1970s and most comprehensively articulated in his landmark monograph, offers a fundamentally different conception of the role of situations in mathematical learning. For Brousseau, a didactical situation is not merely a contextual backdrop but a carefully structured system of interactions among the teacher, the student, and the mathematical milieu (the environment of objects, problems, and constraints that the student encounters).

The central mechanism in TDS is "devolution" (dévoluton), the process by which the teacher transfers responsibility for a mathematical problem to the student, enabling the student to genuinely take ownership of the problem as their own. In Brousseau's framework, the situation is not a passive setting but an active structural arrangement designed to create conditions under which mathematical knowledge can emerge through the student's interaction with the milieu. The student encounters an "a-didactical" situation, one that appears as a genuine problem, not

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as a school exercise, and through adaptation, action, and formulation, constructs mathematical knowledge.

Brousseau distinguishes several types of didactical situations: action situations, where students interact with the milieu through trial and error; formulation situations, where students must communicate their strategies; validation situations, where students must justify their reasoning; and institutionalization situations, where the teacher formally establishes the mathematical knowledge. These types form a progression from situated action to decontextualized knowledge.

The epistemological commitment here is clear: knowledge does not exist prior to the situation; rather, it emerges through the student's engagement with a carefully designed situation. However, Brousseau's situations are fundamentally *didactical*: they are constructed by the teacher with a specific mathematical learning objective in mind. They are not "real-world" situations in the everyday sense, but rather mathematical problem environments designed to provoke specific cognitive processes. This is both the theory's strength and its limitation from the perspective of the Chinese curriculum, which seeks to integrate both real-world and mathematical situations into a unified framework.

A further important aspect of TDS is the concept of "obstacle épistémologique" (epistemological obstacle), the idea that certain difficulties in learning mathematics are not merely errors but reflections of deeper cognitive tensions between the student's existing knowledge and the new knowledge to be constructed. In Brousseau's framework, the didactical situation is designed precisely to bring these obstacles to the surface, enabling students to overcome them through active engagement with the milieu. This concept resonates with the Chinese curriculum's emphasis on situations that "provoke cognitive conflict" (引发认知冲突) to motivate learning, although the Chinese curriculum does not draw explicitly on Brousseau's theoretical apparatus.

The key distinction between Brousseau's conception and the Chinese curriculum's lies in the scope of "situation." For Brousseau, a situation is always a deliberately constructed didactical environment, a microcosm designed by the teacher to elicit specific mathematical reasoning. The Chinese curriculum uses "situation" in a much broader sense, encompassing not only teacher-designed problem environments but also real-world contexts, scientific phenomena, and even open-ended exploratory settings where the mathematical problem is not predetermined but discovered by the student.

2.3 Freudenthal: Reality as the Source Domain of Mathematics

Hans Freudenthal's Realistic Mathematics Education (RME), developed in the Netherlands from the 1970s onward, offers yet another perspective on the situation-problem relationship. Freudenthal (1991) argued forcefully that mathematics must be connected to reality, not as an afterthought or an application, but as its very source. His central concept is "mathematization": the process by which real-world problems are organized, structured, and transformed into mathematical objects and relationships.

Freudenthal distinguished between "horizontal mathematization" (reducing a real-world problem to a manageable mathematical form) and "vertical mathematization" (reorganizing and formalizing mathematical structures within the mathematical domain itself). This distinction is crucial: it acknowledges that the movement from situation to mathematics involves different kinds of cognitive work depending on where one is in the process. The initial encounter with a real-world situation requires a different kind of thinking than the subsequent formalization and generalization of the mathematics that emerges.

For Freudenthal, reality is not a decorative setting but the "source domain" of mathematics. Mathematics is a human activity ("mathematics must be treated as a human activity," Freudenthal, 1991), and this activity begins with the organization of reality. The situation, in this view, is not a container for pre-existing problems but the very ground from which mathematical problems arise.

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This resonates with the Chinese curriculum's emphasis on situations as generative rather than decorative. However, Freudenthal's RME was developed primarily for primary and lower secondary education, and its emphasis on "guided reinvention" through carefully structured problem situations differs from the Chinese curriculum's broader ambition to integrate real-world, mathematical, and scientific situations across all educational stages. Moreover, RME's distinction between horizontal and vertical mathematization, while valuable, does not fully capture the three-fold typology of situations in the Chinese curriculum.

Freudenthal's notion of "guided reinvention" (begeleid her-uitvinden) is particularly relevant here. He argued that students should not be told mathematical knowledge but should be guided to "reinvent" it through their engagement with problem situations. This principle implies that situations must be carefully chosen so that the mathematics to be learned is a natural outgrowth of the student's activity within the situation. The situation, in this sense, is indeed generative: the mathematics emerges from the situation rather than being imposed upon it.

However, Freudenthal's conception of "reality" is somewhat undifferentiated. While he acknowledges that different types of problems require different kinds of mathematization, he does not systematically categorize situations by type or analyze how different situation types may foster different aspects of mathematical thinking. The Chinese curriculum's three-fold typology (real-world, mathematical, scientific) can be seen as an elaboration and systematization of Freudenthal's intuitive recognition that mathematics emerges from engagement with reality, but with the important addition that "reality" itself is multi-layered and requires different kinds of mathematical engagement.

2.4 Situated Learning: Knowledge as Contextually Embedded

A fourth perspective, Lave and Wenger's (1991) theory of situated learning, provides additional insight into the relationship between situations and knowledge. Situated learning theory argues that learning is not the transmission of abstract knowledge but a process of "legitimate peripheral participation" in communities of practice. Knowledge is fundamentally embedded in the situations and activities in which it is used; it cannot be separated from its context without losing its meaning.

While situated learning theory was not developed specifically for mathematics education, it has influenced thinking about contextualized mathematics instruction. Its key contribution is the recognition that situations are not merely external settings for learning but constitutive of the learning itself. What is learned in a situation is different from what can be extracted and applied elsewhere, or at least the relationship between situated knowledge and transferable knowledge is far more complex than traditional instruction assumes.

This perspective adds an important dimension to our comparative analysis: if situations are constitutive of mathematical knowledge (as situated learning theory suggests), then the Chinese curriculum's emphasis on diverse situation types may reflect an implicit recognition that different types of situations foster different kinds of mathematical understanding.

Situated learning theory also raises an important question about transfer. If mathematical knowledge is fundamentally embedded in the situations where it is learned, then exposing students to diverse situation types is not merely a matter of pedagogical variety but a necessary condition for developing flexible, transferable mathematical competence. A student who has only encountered mathematics in real-world situations may struggle when faced with purely mathematical problems; a student who has only worked with mathematical situations may lack the ability to recognize mathematics in everyday life. The Chinese curriculum's insistence on all three situation types (real-world, mathematical, and scientific) can be understood as an implicit acknowledgment of this insight: mathematical competence requires experience across the full range of situations in which mathematics operates.

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III. THE CHINESE CURRICULUM'S CONCEPTION OF PROBLEM SITUATIONS

3.1 Historical Development: From "Double Base" to "Core Competencies"

To understand the current conception of problem situations in Chinese mathematics curriculum, it is necessary to trace its development through successive curriculum reforms. In the 2001 and 2011 curriculum standards, the emphasis was primarily on the "double base" (双基): basic knowledge and basic skills. Situations were used mainly to motivate the introduction of new mathematical concepts, to make abstract ideas more accessible by grounding them in familiar contexts. The situation was, in effect, a pedagogical tool serving pre-determined knowledge objectives.

The 2022 curriculum standards (Ministry of Education, 2022) represent a significant departure from this earlier orientation. Recent textbook analyses have documented how these shifts in curricular emphasis have translated into changes in problem contexts across successive textbook editions (Zhang, Lin, Tian, & Liu, 2025). This shift did not occur in isolation; it was influenced by international trends in mathematics education, including the growing emphasis on mathematical literacy promoted by PISA, the widespread adoption of problem-solving approaches following Polya's (1973/1945) pioneering work, and the increasing recognition of problem posing as a core mathematical competence (Liljedahl & Cai, 2021). Yet the Chinese curriculum's integration of these international ideas into a coherent framework centered on problem situations is distinctly Chinese in character. Influenced by the broader educational reform agenda emphasizing "core competencies" (核心素养), the 2022 standards articulate a vision in which mathematical learning is organized around three overarching competencies, often referred to as the "Three Abilities" (三会): the ability to observe the real world from a mathematical perspective, the ability to think about the real world mathematically, and the ability to express the real world using mathematical language (Ministry of Education, 2022). These competencies are not simply knowledge or skills but integrated capacities that require students to move fluidly between mathematical and extra-mathematical domains.

Within this framework, problem situations are no longer merely pedagogical aids but become constitutive of the learning objectives themselves. The standards explicitly call for students to "discover and pose problems, analyze problems, and solve problems" within situations, a formulation that elevates problem posing from a teaching technique to a core curricular goal. As Li and Xu (2021) documented, problem posing has been a part of Chinese mathematics curriculum reform for over two decades. Early groundwork was laid by Silver and Cai (1996), who examined Chinese students' problem-posing abilities and found that Chinese students showed distinctive patterns in how they formulated problems from given situations. The 2022 standards, however, give problem posing unprecedented prominence by integrating it into the very definition of mathematical competence.

3.2 The Three Types of Situations: An Epistemological Analysis

The Chinese curriculum standards distinguish three types of situations: real-world situations (现实情境), mathematical situations (数学情境), and scientific situations (科学情境). This tripartite classification is not arbitrary; each type serves a distinct epistemological function and engages different cognitive processes.

Real-world situations require what Freudenthal called "horizontal mathematization," namely the translation of messy, ill-structured everyday problems into mathematical form. When students encounter a real-world situation (such as planning a school event, comparing phone data plans, or analyzing household electricity consumption), they must first identify the mathematically relevant aspects of the situation, abstract away irrelevant details, and formulate a mathematical problem. This process of "mathematization" is itself a core mathematical competence, and the Chinese curriculum explicitly connects it to the development of "model awareness" (模型意识) and "application awareness" (应用意识) (Ministry of Education, 2022).

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Mathematical situations operate differently. These are problems internal to mathematics: patterns to be discovered, conjectures to be tested, proofs to be constructed. A mathematical situation might involve investigating the relationship between the sum of interior angles and the number of sides of a polygon, or exploring why certain algebraic transformations preserve equality. Here, the cognitive demand is not mathematization but *formalization*: the movement from informal exploration to rigorous mathematical reasoning. The Chinese curriculum connects mathematical situations primarily to the development of "reasoning ability" (推理能力) and "abstract ability" (抽象能力).

Scientific situations occupy an intermediate position. These draw on contexts from the natural sciences, such as physics experiments, biological growth patterns, chemical concentrations, and astronomical observations, as settings for mathematical reasoning. Scientific situations share features with both real-world and mathematical situations: they require mathematization (like real-world situations), but they also involve a degree of formalization and model-building that goes beyond everyday problem-solving. The Chinese curriculum connects scientific situations to the development of "data awareness" (数据意识) and "model conception" (模型观念), particularly in the context of statistics and probability.

What is crucial, and what distinguishes the Chinese approach from PISA's framework, is that these three types of situations are not treated as interchangeable "contexts" for assessing the same underlying mathematical competence. Rather, each type cultivates a different aspect of mathematical thinking. Real-world situations develop the capacity to *see mathematics in the world*; mathematical situations develop the capacity to *think rigorously within mathematics*; scientific situations develop the capacity to *use mathematics as a tool for understanding natural phenomena*. Together, they form an integrated ecology of mathematical learning.

3.3 Problem Situations as Triple-Function Devices

A distinctive feature of the Chinese curriculum's conception is that problem situations serve a triple function: they are simultaneously cognitive activities (things students do), curricular goals (things students should be able to do), and pedagogical approaches (methods teachers use to organize instruction).

As **cognitive activities**, problem situations engage students in the full cycle of mathematical problem-solving, involving discovering problems within a situation, posing them in mathematical terms, analyzing their structure, and constructing solutions. This cycle mirrors but extends the classic problem-solving framework articulated by Polya (1973) by emphasizing the *pre-solving* phases of problem discovery and problem posing, phases that international research has identified as crucial but often neglected (Liljedahl & Cai, 2021; Cai & Rott, 2024).

As **curricular goals**, problem situations are embedded in the definition of mathematical competence. The "Three Abilities" framework (observing, thinking, expressing) implicitly requires students to be proficient in navigating between situations and mathematics, not just solving well-defined problems, but formulating problems from situations in the first place. This represents a significant expansion of the traditional "double base" conception, which focused primarily on knowledge and skills.

As **pedagogical approaches**, problem situations provide a design principle for teaching. The Chinese curriculum standards recommend that teachers "give full play to the promoting role of situation design and problem posing in students' active participation in teaching activities" (Ministry of Education, 2022, teaching suggestions section). This positions the problem situation not as a brief introduction before the "real lesson" begins, but as the organizing structure for the entire instructional sequence.

This triple function is what makes the Chinese curriculum's conception distinctive. To appreciate its significance, consider how each of the international frameworks examined in this paper handles these functions in isolation: PISA treats situations primarily in their assessment function (as contexts for measuring competence); Brousseau's TDS treats them primarily in their pedagogical function (as structures for organizing teaching); Freudenthal's RME treats them primarily in their cognitive function (as sources for mathematization); and Lave and Wenger's situated learning theory focuses on the ontological function (situations as constitutive of knowledge itself). The Chinese curriculum's integration of all these functions within a single conception of "problem situation" reflects a holistic understanding of the situation-problem relationship that no single international framework fully captures.

IV. COMPARATIVE ANALYSIS: AN EPISTEMOLOGICAL SPECTRUM OF SITUATIONS

4.1 From Instrumental to Generative: Mapping the Terrain

The four frameworks examined in this paper can be arranged along an epistemological spectrum based on how they conceptualize the relationship between situations and mathematical knowledge. At one end lies the instrumental conception, where situations are tools for assessing or displaying pre-existing mathematical knowledge. At the other end lies the generative conception, where situations are the ground from which mathematical understanding emerges.

PISA's framework represents a clearly instrumental position. The mathematical content is defined independently of the situations in which it is assessed; situations are selected to provide variety and authenticity, but they do not fundamentally alter what is being measured. A student who "has" mathematical literacy can demonstrate it in any of the four PISA context types (personal, occupational, societal, scientific), because the underlying competence is situation-independent.

Brousseau's TDS occupies an intermediate position. While situations in TDS are generative in the sense that mathematical knowledge emerges through interaction with the didactical milieu, the situations themselves are deliberately constructed by the teacher with a specific mathematical objective in mind. The generation is "top-down": the teacher designs the situation to lead to a predetermined mathematical insight. The student's role is to discover this insight within the structured environment.

Freudenthal's RME moves further toward the generative end. In RME, the real-world situation is not designed to elicit a specific mathematical response but serves as the "source domain" from which mathematical concepts organically emerge through the process of mathematization. The emphasis on "guided reinvention" means that students should, in principle, be able to reconstruct mathematical knowledge from their engagement with reality, with the teacher providing scaffolding rather than a predetermined path.

The Chinese curriculum occupies the most complex position on this spectrum. It embraces generative situations (real-world situations as sources for mathematization), structured situations (mathematical situations as carefully sequenced problems that build mathematical reasoning), and applied situations (scientific situations as contexts for mathematical modeling), all within a single integrated framework. This complexity reflects the curriculum's ambition to develop the full range of mathematical competencies, from informal sense-making to rigorous formal reasoning.

4.2 The Three-Fold Typology: Complementing International Frameworks

The Chinese curriculum's three-fold typology of situations (real-world, mathematical, scientific) can be understood as an implicit response to a gap in international frameworks. PISA's four context types (personal, occupational, societal, scientific) are all "real-world" contexts; PISA does not explicitly include purely mathematical situations (problems internal to mathematics, such as exploring patterns or constructing proofs) as a separate category. While PISA does include a "scientific" context, this is treated as one of four interchangeable real-world wrappers rather than as a distinct epistemological category with specific cognitive demands. In PISA, mathematical reasoning per se is assessed through word problems embedded in one of these real-world contexts.

Brousseau's TDS, conversely, deals almost exclusively with mathematically structured situations. The "milieu" is a carefully designed mathematical environment, not a real-world context. While this allows for precise analysis of the teaching-learning dynamics, it limits the theory's applicability to contexts where students encounter messy, ill-structured problems from everyday life or the sciences.

Freudenthal's RME, with its emphasis on "reality" as the starting point, addresses real-world situations but does not systematically distinguish between different types of non-mathematical contexts. The distinction between horizontal and vertical mathematization captures the movement from reality to formal mathematics, but it does not differentiate among the types of reality that students encounter.

The Chinese curriculum's typology fills these gaps by explicitly recognizing that different situation types serve different educational purposes. Real-world situations develop application awareness and model consciousness; mathematical situations develop abstract reasoning and formal proof skills; scientific situations develop data literacy and modeling competence. Rather than treating these as competing approaches, the Chinese curriculum integrates them as complementary components of a comprehensive mathematics education.

To illustrate the practical significance of this distinction, consider how the topic of probability and statistics is treated in the Chinese curriculum versus in PISA. In PISA, a statistics or probability item is embedded in one of four context types, such as a personal context like predicting weather or a societal context like interpreting poll results. The mathematical competence being assessed (understanding probability, interpreting data) is the same regardless of context. In the Chinese curriculum, by contrast, the same mathematical topic is approached through all three situation types with distinct purposes. A real-world situation might involve students collecting and analyzing data about their classmates' heights (developing data awareness). A mathematical situation might involve exploring the theoretical probability of different outcomes when rolling two dice (developing abstract reasoning about chance). A scientific situation might involve analyzing experimental data from a biology experiment on plant growth under different conditions (developing modeling competence). Each situation type contributes a different facet of statistical thinking, and the curriculum expects students to develop proficiency across all three.

This three-fold approach also connects to the Chinese curriculum's emphasis on cross-disciplinary thematic learning in the 2022 revision. The scientific situation type, in particular, serves as a bridge between mathematics and the natural sciences, encouraging students to see mathematics not as an isolated discipline but as a tool for understanding and modeling natural phenomena. This interdisciplinary orientation goes beyond what PISA's framework captures, where scientific contexts are merely one of four flavors for assessment items rather than a distinct epistemological category with its own cognitive demands.

4.3 The Internal Tension: A Productive Ambiguity

It would be misleading to suggest that the Chinese curriculum's conception is without tensions. The three-fold typology of situations, while intuitively appealing, raises important questions about the boundaries between categories. Is a problem about the trajectory of a thrown ball a "real-world" situation or a "scientific" one? Is a pattern-finding task using physical manipulatives a "mathematical" situation or a "real-world" one? The curriculum standards do not provide sharp criteria for distinguishing among the three types, and this ambiguity could lead to confusion in implementation.

However, we argue that this ambiguity is not a flaw but a *productive feature* of the framework. In practice, mathematical problems are rarely purely "mathematical" or purely "real-world"; they exist on a continuum. The three-fold typology serves as an orienting framework rather than a rigid classification system, and the boundaries between types are necessarily porous. This flexibility allows teachers to design rich, multi-layered situations that draw on multiple types simultaneously; a shopping budget problem may involve real-world financial reasoning, mathematical optimization, and scientific estimation.

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Moreover, the three types correspond to different epistemological processes, as noted earlier: mathematization for real-world situations, formalization for mathematical situations, and modeling for scientific situations. These processes are not mutually exclusive but represent different emphases within the broader activity of mathematical thinking. The Chinese curriculum's implicit recognition of this complementarity is, we suggest, one of its most distinctive contributions.

This perspective also connects to a broader debate in mathematics education about the relationship between contextualized and decontextualized mathematical knowledge. Some scholars have argued that all mathematical knowledge is ultimately decontextualized, holding that the goal of mathematics education is to help students abstract away from specific situations to arrive at general, transferable principles. From this perspective, the Chinese curriculum's emphasis on diverse situation types might appear to privilege context over abstraction. However, this interpretation misunderstands the Chinese framework. The three situation types are not ends in themselves but are means to different kinds of mathematical abstraction. Real-world situations develop the capacity to abstract mathematical structure from messy reality; mathematical situations develop the capacity to reason within abstract structures; scientific situations develop the capacity to build models that mediate between the abstract and the concrete. Together, they cultivate a full spectrum of abstraction capacities, from concrete to formal to applied.

This interpretation is supported by the curriculum's developmental progression (discussed in Section 5), which moves from predominantly real-world situations in early years to predominantly mathematical situations in later years. The trajectory is clearly toward increasing abstraction and formalization, but the point of departure is always a situation of some kind, and the curriculum maintains that even at the most advanced levels, mathematical reasoning retains its connection to situations, whether mathematical or scientific. This represents a subtle but important departure from educational traditions that treat abstraction and situation as opposing forces.

The distinctiveness of the Chinese approach can be understood in light of broader characteristics of East Asian mathematics education. Leung (2001) has identified several features of East Asian mathematics education, including emphasis on mathematical problem-solving, a strong connection between mathematics and everyday life, and the use of variation in problem design, all of which resonate with the Chinese curriculum's multi-layered approach to situations. The Chinese curriculum's treatment of problem situations can thus be seen not as an isolated innovation but as an expression of deeper cultural and pedagogical commitments that distinguish East Asian mathematics education from Western traditions.

V. CROSS-STAGE DEVELOPMENT OF PROBLEM SITUATIONS

The Chinese curriculum standards articulate a developmental progression for problem situations across three educational stages: elementary school (Grades 1-6), junior secondary school (Grades 7-9), and senior secondary school (Grades 10-12). This progression reflects a sophisticated understanding of how students' relationships with situations evolve as their mathematical maturity increases.

5.1 Elementary School: Situations as Concrete Experience

At the elementary level, the curriculum emphasizes real-world situations drawn from students' daily lives. Young students are encouraged to discover mathematical problems in familiar contexts: shopping, sharing, measuring, arranging objects. The cognitive demand is primarily at the level of *awareness* (意识), what the curriculum calls "application awareness" (应用意识) and "model awareness" (模型意识). Students are not expected to formalize their reasoning but to develop an intuitive sense that mathematics is relevant to and can be found in the world around them.

This emphasis aligns with Freudenthal's principle that mathematics education should begin with "reality" as

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the source domain. At this stage, the situation is indeed generative: mathematical concepts emerge from students' engagement with concrete, familiar situations. The curriculum's focus on real-world situations at this level also resonates with PISA's emphasis on personal and societal contexts, though the Chinese curriculum does not frame this in terms of assessment but in terms of developmental appropriateness.

For example, consider the topic of fractions in the Grade 4-5 curriculum. Students are presented with real-world situations such as dividing a pizza among friends, measuring ingredients for a recipe, or sharing a length of rope equally. These situations are designed so that the concept of fraction emerges naturally from the need to represent quantities that cannot be expressed as whole numbers. The situation is genuinely generative: the mathematical concept (fractions as parts of a whole, as division, as points on a number line) arises from the student's engagement with the concrete situation, rather than being imposed upon it.

Similarly, in the Grade 3 curriculum, students encounter problems such as determining how many tables and chairs are needed for a class party given certain constraints, or figuring out how to divide a length of ribbon equally among classmates. These situations are drawn from students' immediate experience and require only basic arithmetic operations. The mathematical content (division, multiplication) is not presented as abstract knowledge to be memorized but as a tool that emerges naturally from the need to solve the situation. This embodies the generative conception: the situation gives rise to the mathematics, rather than the mathematics being illustrated by the situation.

5.2 Junior Secondary School: Situations as Bridges to Abstraction

At the junior secondary level, the curriculum introduces a more balanced mix of all three situation types. Real-world situations remain important but become more complex and less familiar; students encounter problems involving statistics, probability, and algebraic modeling that require them to abstract from the concrete situation and reason at a higher level of generality. Mathematical situations gain prominence as students engage with proof, conjecture, and formal reasoning. Scientific situations appear in contexts involving data analysis, experimental design, and the quantitative reasoning that connects mathematics to the natural sciences.

The developmental shift at this stage is from *awareness* (意识) to *conception* (观念). The curriculum speaks of "model conception" (模型观念) and "application conception" (应用观念) at this level, terms that suggest a more conceptual and less purely experiential relationship with situations. Students are expected not merely to notice mathematics in the world but to understand how mathematical structures operate within different types of situations.

This stage corresponds roughly to what Brousseau described as the transition from "action" to "formulation" and "validation" in didactical situations. The Chinese curriculum, however, does not restrict this transition to mathematically structured environments; it expects students to navigate it across real-world, mathematical, and scientific situations.

Consider, for instance, how the concept of function is treated across the curriculum. In Grade 8, students encounter functions through real-world situations (e.g., the relationship between travel time and distance at constant speed) and scientific situations (e.g., the relationship between temperature and time during heating). These situations serve as the ground from which the abstract concept of function emerges. By Grade 9, students are expected to work with functions in mathematical situations (e.g., analyzing the properties of quadratic functions, comparing different function families), where the cognitive demand shifts from mathematization to formalization and generalization. This progression illustrates how the same mathematical content is approached through different situation types at different developmental stages, with each situation type contributing a distinct dimension to students' understanding.

5.3 Senior Secondary School: Situations as Platforms for Mathematical Reasoning

At the senior secondary level, as articulated in both the senior high school curriculum standards (Ministry of Education, 2020) and the 2022 compulsory education standards (Ministry of Education, 2022), the curriculum emphasizes mathematical and scientific situations over real-world ones. Students engage with abstract mathematical structures, formal proofs, and sophisticated modeling tasks. Real-world situations at this level are complex and often ill-structured, requiring students to make assumptions, choose appropriate mathematical tools, and justify their modeling decisions.

The developmental marker at this stage is the shift from *conception* (观念) to *ability* (能力). The curriculum speaks of "abstract ability" (抽象能力), "reasoning ability" (推理能力), and "mathematical modeling ability" (数学建模能力). At this level, situations are platforms for exercising mature mathematical competencies rather than sources for discovering new concepts. The generative role of situations has been partially superseded by their role as testing grounds for sophisticated mathematical reasoning.

This progression, from awareness to conception to ability, from real-world to mathematical to scientific situations, and from concrete to abstract, reflects a coherent developmental logic. It also suggests that the Chinese curriculum's three-fold typology is not a static classification but a dynamic framework that evolves as students' mathematical maturity grows. Different situation types are not simply "different flavors" but represent progressively deeper modes of engagement between the student and the mathematical world.

VI. DISCUSSION: CONTRIBUTIONS AND IMPLICATIONS

6.1 What the Chinese Curriculum Offers International Discourse

The comparative analysis in this paper reveals that the Chinese curriculum's conception of problem situations offers several contributions to international mathematics education discourse.

First, the triple-function conception of problem situations, as cognitive activities, curricular goals, and pedagogical approaches, provides a more integrated framework than most international alternatives. Where PISA treats situations primarily as assessment contexts, Brousseau treats them as teaching structures, and Freudenthal treats them as sources for mathematization, the Chinese curriculum recognizes that these functions are not mutually exclusive but are different dimensions of the same phenomenon. This integrated view has practical implications: it suggests that curriculum designers should not treat "situational problems" as a single category of tasks but should consider how situations function differently in different pedagogical and curricular roles.

Second, the three-fold typology of situations (real-world, mathematical, scientific) provides a finer-grained analytical tool than most international frameworks. PISA's four context types, for instance, all fall within the "real-world" category of the Chinese typology; PISA does not explicitly distinguish between purely mathematical situations and scientifically-grounded situations. By making these distinctions explicit, the Chinese curriculum enables more precise analysis of what different types of situations contribute to mathematical learning.

Third, the cross-stage developmental progression, from awareness to conception to ability with corresponding shifts in the dominant situation type, provides a model for understanding how students' relationships with mathematical situations evolve over time. This developmental perspective is largely absent from international frameworks, which tend to treat situations as static categories rather than as evolving dimensions of mathematical competence.

6.2 Toward a Dialogical Understanding

The comparative analysis also raises important questions for the Chinese curriculum itself. The distinction between real-world, mathematical, and scientific situations, while useful as an orienting framework, requires further theoretical elaboration. What criteria distinguish a "scientific" situation from a "real-world" one? How should curriculum designers handle problems that straddle multiple categories? The

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concept of "epistemological demands": mathematization, formalization, and modeling, which correspond to different situation types offers a promising direction for future research, but it requires more precise definition and empirical validation.

Moreover, the Chinese curriculum's emphasis on situations as generative grounds for mathematical knowledge raises questions about the relationship between situation-based learning and the systematic development of mathematical structures. Brousseau's TDS demonstrates that carefully designed didactical situations can be more effective than unstructured real-world problems for developing specific mathematical concepts. The challenge for the Chinese curriculum is to balance the generative potential of real-world situations with the precision and efficiency of mathematically structured ones.

These questions are not criticisms but indications of the richness of the Chinese curriculum's conception. The fact that it raises such questions, and that it invites dialogue with international theoretical traditions, is a sign of its intellectual vitality.

It is also worth noting that the Chinese curriculum's conception of problem situations has evolved in dialogue with international ideas, even if this dialogue is not always made explicit. The emphasis on mathematical modeling in the senior high school curriculum shows clear influence from international modeling research and the PISA framework. The emphasis on discovering and posing problems resonates with the international problem-posing literature (Brown & Walter, 2005; Liljedahl & Cai, 2021). The emphasis on real situations echoes Freudenthal's insistence on reality as the source of mathematics and the situated learning tradition (Lave & Wenger, 1991). What is distinctive about the Chinese curriculum is not that it borrows from these international traditions but that it integrates them into a coherent, multi-layered framework that goes beyond any single international source. This integrative capacity is itself a form of theoretical contribution, and it deserves more attention from the international mathematics education community.

6.3 Implications for Practice

For mathematics educators and curriculum designers, the analysis suggests several practical implications:

1. **Situation design should be intentional and differentiated.** Not all situations serve the same purpose. Teachers should consider what kind of mathematical thinking a situation is designed to develop and choose situation types accordingly. A lesson aimed at developing mathematical reasoning may benefit from a mathematical situation, while a lesson aimed at developing application awareness may require a real-world situation.
2. **Problem posing should be treated as a core competence.** The Chinese curriculum's emphasis on problem posing, as both a cognitive activity and a curricular goal, resonates with international research (Brown & Walter, 2005; Cai & Hwang, 2022; Liljedahl & Cai, 2021) that has identified problem posing as a crucial but underdeveloped aspect of mathematical competence. Curriculum designers worldwide should consider how to systematically incorporate problem-posing opportunities into their programs.
3. **Cross-stage progression should be explicit.** The Chinese curriculum's developmental logic, from concrete real-world situations in early years to abstract mathematical situations in later years, provides a useful model for curriculum coherence. International curriculum frameworks should consider how situations develop across grade levels rather than treating them as grade-independent categories.
4. **The epistemological dimension of situations should be made explicit.** The Chinese curriculum's implicit recognition that different situation types entail different epistemological demands (mathematization, formalization, modeling) is a significant insight that deserves further development. International research on mathematical modeling (Blum, 2015; Blum & Leiß, 2007), problem posing (Brown & Walter, 2005; Cai & Hwang, 2022), and situated learning (Lave & Wenger, 1991) could profitably engage with this distinction, examining how different

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types of situations foster different modes of mathematical thinking and how curriculum designers can intentionally vary situation types to develop the full range of mathematical competencies.

VII. CONCLUSION

This paper has examined the Chinese curriculum's conception of "problem situations" through comparative analysis with four major international frameworks: PISA's mathematical literacy framework, Brousseau's Theory of Didactical Situations, Freudenthal's Realistic Mathematics Education, and Lave and Wenger's theory of situated learning. The analysis reveals that the Chinese curriculum embodies a distinctive epistemological stance in which situations are not decorative backgrounds but generative grounds for mathematical knowledge. This stance is expressed through a three-fold typology of situations (real-world, mathematical, scientific), each associated with distinct epistemological demands (mathematization, formalization, modeling), and through a triple-function conception of situations as simultaneously cognitive activities, curricular goals, and pedagogical approaches.

The cross-stage developmental analysis further shows that the Chinese curriculum envisions a coherent progression in students' relationships with situations, moving from awareness-based engagement with real-world contexts in elementary school, through conception-based navigation of diverse situation types in junior secondary school, to ability-based reasoning within complex mathematical and scientific situations in senior secondary school.

While the Chinese curriculum's conception is not without internal tensions, particularly regarding the boundaries between situation types and the balance between generative and structured approaches; these tensions are productive rather than debilitating. They invite further theoretical refinement and empirical investigation, and they open spaces for productive dialogue between Chinese and international mathematics education communities.

Looking ahead, several directions for future research emerge from this analysis. First, empirical studies are needed to examine how Chinese mathematics teachers actually implement the three-fold typology of situations in their classrooms. Do teachers distinguish among real-world, mathematical, and scientific situations in their instructional design? Do they recognize the different epistemological demands associated with each type? Second, comparative studies could examine how students in different educational systems develop different relationships with mathematical situations, and whether these differences have measurable effects on mathematical competencies. Third, theoretical work is needed to further develop the concept of "epistemological demands" associated with different situation types, connecting it to existing research on mathematization, formalization, and modeling.

The broader implication is that the concept of "situation" in mathematics education is far richer and more complex than any single framework can capture. PISA's instrumental view, Brousseau's structural approach, Freudenthal's mathematization perspective, and situated learning's emphasis on the constitutive role of context each illuminate important aspects of the situation-problem relationship. The Chinese curriculum's integrative conception, while less analytically precise, captures a holistic reality: that situations in mathematics education serve multiple functions simultaneously, and that their educational value depends not on their type alone but on how they are designed, implemented, and connected to the broader goals of mathematical learning.

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