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Instructional Design through the Gerlach and Ely Model in Elementary Science Education: Implications for Fostering Systems Thinking and Creative Capacities in the Saudi Context

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Abstract

Objective: This paper will present an overview of a structured review of the theory and evidence for using the Gerlach and Ely (GEM) Instructional Design Model in elementary science education in a way that supports the development of system thinking skills and creative abilities among sixth-grade students in the Saudi education system. **Methodology:** A structured analytical review method was used as the primary methodology for this review. The majority of the literature reviewed is from the theoretical framework, empirical background, and literature citations from the doctoral dissertation on GEM-based instructional modules in elementary science education in Saudi Arabia. The literature reviews synthesized instructional design principles, systems thinking frameworks, and creativity theories referenced in the foundational dissertation. **Results:** The findings of this review indicate that the alignment between the objectives, content organization, instructional strategy, and assessments provided through the GEM model creates a pedagogically cohesive learning environment that could foster higher-order thinking for students. When implemented in a systematic and intentional way, the GEM model-based instructional modules have demonstrated strong theoretical alignment with supporting systems thinking and enhancing creative abilities in students (particularly in terms of flexibility, elaboration, and originality). **Limitations / Implications:** This review has highlighted the need for additional research to provide evidence for integrating instructional design models (such as the GEM model) with systems thinking and creative abilities in elementary science education. Empirical studies are needed to validate the effectiveness of the GEM model-based integrated interventions at different grade levels and in different educational settings. **Originality / Value:** This paper extends the current body of knowledge by providing an analytical link between instructional design theory, systems thinking, and creative capacity in an elementary science framework designed for use in the Saudi educational setting. The review is further positioned within contemporary global reform agendas that emphasize systemic literacy and creative adaptability in elementary education.

Keywords: Gerlach and Ely Model, Instructional Design, Systems Thinking, Creative Abilities, Elementary Science Education, Saudi Arabia

Introduction

Contemporary Demands in Science Education and the Need for Structured Instructional Design

Contemporary science education has undergone a significant transformation from primarily focusing on acquiring factual knowledge to intentionally cultivating higher-order cognitive abilities in students. The increasing focus in international education reform agendas on analytical reasoning, complex problem solving, and the ability to think conceptually about the interconnectedness of scientific phenomena (as opposed to separate variables) (National Research Council [NRC] 2012; OECD, 2018) demonstrates an increasing agreement among educators that students should have access to cognitive tools to address complexity, ambiguity, and non-linearity in natural and technological systems (Senge, 1990; Meadows, 2008). In addition, current standards-based perspectives continue to reinforce the notion that "systems and system models" are fundamental lenses through which scientific understanding is constructed across topics and grade levels (NGSS Lead States 2013). Therefore, there is a growing recognition of the necessity for coherent learning progressions that make systems reasoning both teachable and assessable in classrooms (National Academies of Sciences, Engineering, and Medicine, 2013).

Recent International Research Supports The Need To Integrate Systems Thinking Into Structured Science Instruction. Research has shown there is an increasing amount of both conceptual and empirical research that indicates it is necessary to intentionally link systems thinking with instructional modeling practices to provide students with tools to navigate complexity and uncertainty in science (Lankers et al., 2023; Bielik et al., 2023).

These studies also suggest that systems thinking needs to be operationalized using intentional instructional architecture to create an environment where systems thinking can occur, rather than just being treated as a cognitive skill.
In addition, two recent bibliometric studies have documented a rapid growth globally of research related to systems thinking in science education over the last five years and therefore document both the need for conceptual expansion as well as the need for systems thinking to be integrated into the instruction process more clearly (Sari et al., 2025; Budak & Ceyhan, 2024).

Perspectives on systems-oriented science education emphasize that students must be able to identify components, analyze relationships, understand feedback mechanisms, and recognize patterns of change over time to develop a meaningful scientific understanding (Assaraf & Orion, 2010; Ben-Zvi-Assaraf & Orion, 2005). Developing these competencies requires more than memorizing information and, so, needs clear instructional support to help students build connected, integrated knowledge. Absent structured pedagogical support, students tend to generate fragmented understandings that inhibit deep, conceptual reasoning (Hmelo-Silver et al., 2017). Furthermore, the lack of structured instructional support during student inquiry or discovery activities increases the likelihood of poor learning outcomes, especially for novice learners, due to the limitations associated with minimal guidance (Mayer, 2004). These factors further support the assertion that producing higher-level outcomes will depend on how learning experiences are designed and sequenced to facilitate stable, complex reasoning. In particular, the importance of early cognitive structuring is evident in elementary education. Early learning experiences define students' subsequent epistemological orientations and potential for abstract and integrative reasoning (English, 2016; Ben-Zvi-Assaraf & Orion, 2005). As well, the majority of elementary science education instruction tends to be teacher-centered and transmission-oriented, limiting opportunities to cultivate intellectual flexibility, relational reasoning, and adaptive problem solving. By contrast, research-based perspectives highlight the critical role that instructional clarity, feedback cycles, and alignment between learning objectives and assessment play in developing high-quality learning outcomes (Hattie, 2009). So, elementary science education should include instructional environments that encourage higher-order thinking by aligning the purposes of the learning experience, the learning tasks, and assessments in a way that builds complexity and helps learners explain phenomena using systemic explanations.

Global curriculum reform movements, along with increasing socio-scientific complexities like climate change, sustainability transition, artificial intelligence integration, and digital transformation, are forcing educational systems to incorporate higher levels of integrative reasoning at an earlier stage of schooling. As such, international policy analysis is increasingly emphasizing that learners need to acquire more than just discipline-specific knowledge but, rather, be able to develop systemic literacy, creative adaptability, and the ability to navigate uncertainty in complex, interconnected systems around the globe (OECD, 2023; UNESCO, 2022). Alongside this broader socio-educational transformation, elementary science education can no longer be seen as merely a stage for accumulating knowledge but, rather, as a key site for shaping students' long-term cognitive dispositions toward complexity, innovation, and responsible citizenship. Therefore, clear instructional frameworks that will help educational designers integrate their teaching practice to meet the demands of large-scale societal changes are an urgent area of research.

In the Saudi context, the national education reform agenda emphasizes innovation, critical thinking, and learner-centered teaching and learning as part of a broader set of national development initiatives (Ministry of Education 2019). Specifically, Saudi Vision 2030 explicitly identifies the refinement of curricula, the professional development of teachers, and the enhancement of the overall quality of education as key elements necessary to meet the emerging societal and labor market demands (Government of Saudi Arabia 2016). Further, institutional efforts to improve the evaluation and assessment capacity of the education system (OECD, 2024) support the ambitions articulated in the national vision. Still, achieving these goals will depend on developing instructional design frameworks that connect instructional objectives, content organization, instructional strategy, and evaluation procedures. Otherwise, higher-order outcomes such as systems thinking and the development of creative capacities may remain policy statements rather than become sustained classroom practices.

Instructional Design Models provide the theoretical and procedural architecture for designing learning experiences systematically and purposefully (Reigeluth & Carr-Chellman, 2009). Of the various Instructional Design Models available, the Gerlach and Ely Instructional Model (Gerlach & Ely, 1980) provides a flexible and structured framework that integrates specifying instructional goals, sequencing content, selecting resources, developing instructional strategies, and assessing within a connected system. Because it shows how instructional components are connected and how instructional design is iterative, the Gerlach and Ely model is a system-wide approach that fits today's need for integrated reasoning. Using this model to guide instructional design in elementary science can help create a scaffold to connect ideas, reason dynamically, and think creatively, all essential skills in developing systems thinking and innovative problem-solving.

Systems Thinking in Elementary Science Education

Systems thinking has been recognized as a key high-order cognitive skill for the understanding of complex scientific systems. Systems thinking differs from linear or reductionistic views of knowledge because it includes the identification of components within a system, the determination of relationships among those components, the interpretation of feedback loops within a system, and the comprehension of dynamic system behaviors over time (Ben-Zvi-Assaraf & Orion, 2005; Meadows, 2008; Senge, 1990). Systems thinking allows students to create a comprehensive mental model that can demonstrate non-linear causality, multi-level interactions, and emergent properties found in natural systems (Hmelo-Silver et al., 2017; Jacobson & Wilensky, 2006). The current science standards provide additional emphasis to the use of systems thinking by formally establishing "systems and system models" as a cross-cutting concept that will facilitate a cohesive knowledge structure across various scientific disciplines (NGSS Lead States, 2013).

Systems thinking is specifically important in many areas of science education, including ecological systems, climate systems, energy conversion systems, and biological regulatory systems, where phenomena cannot be accurately described using isolated variables (Ben-Zvi-Assaraf & Orion, 2005; Assaraf & Orion, 2010). Students must begin to move beyond superficial recall of information to relational reasoning that describes how changes to one component of a system affect other components of the same system. Research has indicated that students who receive no direct scaffolding in their learning of systems thinking typically utilize fragmented causal descriptions of systems, which do not take into consideration the interdependence of all components within the system (Chi et al., 2012; Hmelo-Silver et al., 2017). Therefore, design-oriented views suggest that there needs to be a deliberate progression in student learning as well as specific and intentional representations that support the coordination of multiple variables and temporal dynamics in systems (National Academies of Sciences, Engineering, and Medicine, 2013).

There exist both potential and challenges in developing systems thinking skills at the elementary school level. Research has demonstrated that students in the upper-elementary grades can identify the structure of a system, recognize cyclic patterns within a system, and engage in reasoning that utilizes feedback loops when they are provided instruction that is structured and supportive of this type of learning (Assaraf & Orion, 2010; Riess & Mischo, 2010). However, the cognitive complexities involved in dynamic reasoning and the integration of multiple variables require instructionally designed environments that progressively support the increase in complexity (Jacobson & Wilensky, 2006; Yoon et al., 2018). A long-standing tradition in the field of system dynamics suggests that understanding of systems is enhanced when students are engaged in explicit modeling practices that make feedback loops, delay mechanisms, and accumulation processes visible (Sterman, 2000). This suggests that educational instruction should provide a framework to turn abstract systems concepts into learnable routines.

Additionally, systems thinking is highly related to the learning of models, simulations, and inquiry-based pedagogy that allows students to modify variables and experience the effects

of these modifications on the overall system (Wilensky & Resnick, 1999; Hmelo-Silver et al., 2017). Models and simulations, along with reflective dialogue, enable students to visualize feedback loops, temporal delays, and non-linear causalities, which are essential to being scientifically literate in today's world (OECD, 2018). Moreover, the development of systems thinking appears to be cumulative, and therefore, repeated exposure to interconnected representations of systems at different grade levels is beneficial (Assaraf & Orion, 2010). Although systems thinking is increasingly viewed as an important element of elementary education, the degree to which systems thinking is embedded in elementary curricula varies greatly. While several conceptual frameworks exist to describe the reasoning skills needed to think about systems (Meadows, 2008; Richmond, 1993), few studies have addressed how formal instructional design models may intentionally include systems thinking goals into the architecture of lessons. Most existing research concerning systems thinking in elementary education has focused on cognitive outcomes while leaving unexplored the instructional mechanisms that support the development of these outcomes (Hmelo-Silver et al., 2017).
This review is intended to close the gap between cognitive theories of systems thinking and classroom instructional practice, with particular emphasis on elementary science education, where foundational reasoning patterns are developed and solidified.

The evidence base for systems thinking emerging from early elementary instructional contexts continues to build in support of the idea that systems thinking can be intentionally developed through instructional design that includes modeling cycles, structural scaffolding, and developmental matching. For example, Alazri & Shahat (2025) demonstrated through their research that upper-elementary level learners who experienced structured STEM-based instructional interventions were able to understand better and identify system component parts as well as relationship or dynamic parts of the system. More recently, researchers have conducted classroom-based studies and have identified that the inclusion of explicit modeling and feedback loop instructional practices supported learners' ability to coordinate multiple variables across time (Lankers et al., 2023). Collectively, these studies provide additional support to the assertion that systems thinking is not simply an emergent property of being exposed to inquiry-based learning experiences, but rather a competency that has to be designed into instruction.

Creative Abilities in Elementary Science Education
The recognition of creativity in science education has evolved in recent years from being a supplementary enrichment experience to now being viewed as a key component of meaningful learning experiences (Runco & Jaeger, 2012). Scholars have defined creativity as the ability to create something new and useful (Runco & Jaeger, 2012), providing a broad-based definition for research on creativity (Runco & Jaeger, 2012). Educational psychologists view creativity as an important aspect of learning that needs to be taught and assessed within the learning environment and instructional goals, rather than as a standalone concept or measure of student creativity (Plucker et al., 2004).

In terms of developing creative thinking in science classrooms, creative thinking extends far beyond generating divergent thoughts to include epistemic curiosity, conceptual risk-taking, and adaptive restructuring of prior knowledge (Craft, 2005; Kind & Kind, 2007).

In terms of assessing creative thinking, the creative abilities of students are typically assessed using measures such as flexibility, elaboration, and originality. These assessments are commonly used in the classroom setting, and may use assessment tools such as the Torrance Tests of Creative Thinking (TTCT) (Torrance, 1974). However, there is growing evidence suggesting that creativity in STEM fields involves not just the ability to generate and elaborate upon ideas, but also the ability to integrate and apply knowledge to solve problems and develop explanations (Henriksen et al., 2016; Park et al., 2016). There is increasing evidence that the assessment of creativity in the science field can be achieved using structured assessment methods that align creative thinking with scientific thinking and problem solving (Hu & Adey, 2002). Many studies have shown that motivation and the learning environment play a significant role in shaping a student's creative performance, and that the instructional environment plays a significant role in the development of student creativity (Amabile, 1996). For students at the elementary school level, creativity enhances their ability to inquire, formulate hypotheses, build representations, and reason about their findings (Kind & Kind, 2007; Vongkulluksn et al., 2018). By encouraging students to generate alternative explanations, model phenomena, and collaborate in their thinking, students will begin to think at a deeper level of epistemological engagement. Research has demonstrated that students who are provided with structured opportunities to investigate and explore open-ended questions will demonstrate enhanced ability to restructure prior knowledge and develop new conceptual connections (Beghetto & Kaufman, 2014; Park et al., 2016). Internationally, many scholars and educators recognize that creativity and critical thinking are skills that can be explicitly taught and developed through explicit curricula and aligned assessments (Vincent-Lancrin et al., 2019).

There is substantial evidence that creativity and systems thinking have common foundational cognitive processes that involve relationship building and integration of ideas. For example, systems thinking requires that individuals identify relationships between elements, understand the dependence between elements, and interpret how different elements interact with each other over time (Ben-Zvi-Assaraf & Orion, 2005; Meadows, 2008). Analogously, creative thinking requires that individuals shift their perspective, rebuild relationships between ideas, and elaborate ideas that are connected (Beghetto & Kaufman, 2014; Henriksen et al., 2016). Furthermore, research in complex problem-solving indicates that generative and systemic thinking occur together when students are engaged in multidimensional scientific tasks (Hmelo-Silver et al., 2017; Yoon et al., 2018). Additionally, developmental theories suggest that creativity exists across multiple levels and that "mini-c" creativity that occurs during learning and conceptual changes can be fostered as part of everyday classroom learning, rather than only as exceptional performance (Kaufman & Beghetto, 2009).

Although there is considerable theory supporting the alignment of creative thinking and systems thinking, instructional practices rarely align these two types of thinking. Most traditional science teaching practices emphasize accuracy, procedural proficiency, and convergent thinking, potentially limiting exploratory thought and intellectual risk-taking (Craft, 2005; Kind & Kind, 2007). Therefore, the inclusion of creative thinking development into science teaching requires planned instructional approaches that provide learning goals, varied strategies, continuous feedback, and opportunities for expanding concepts. From an instructional design perspective, models that provide alignment of instructional objectives, content sequencing, strategy choice, and evaluation procedures provide a cohesive approach to incorporating creative performance indicators into classroom practices (Reigeluth & Carr-Chellman, 2009).

International assessments conducted recently support the idea that creativity is becoming a more important aspect of what students are to learn in school. The OECD's (2023) framework for creative thinking emphasizes that, when it comes to creativity and education, the process includes creating a variety of different ideas, comparing the options you create, and then refining your solution to a problem, all of which occur within a structured environment where problems are solved. Additionally, contemporary reviews of how creativity can be incorporated into STEM education suggest that educators must include creativity as part of their curriculum architecture with the use of explicit task designs and by providing students with opportunities to refine their work iteratively, and assess student creativity in addition to using psychometric instruments (Demircali, 2025). Therefore, these recent changes support the idea that, like systems thinking, creativity will benefit from a clear instructional structure built into classroom teaching practices.

The Gerlach and Ely Instructional Model as an Integrative Framework

Instructional design models are structured systems designed to promote an organized approach to designing learning experiences while systematically aligning educational objectives, content, strategies, and assessments (Reigeluth & Carr-Chellman, 2009). Using instructional design models helps students engage meaningfully and keeps intended instructional outcomes aligned with the instructional process. Classical instructional design frameworks include the Gerlach and Ely Model (Gerlach & Ely, 1980), which offers a complete and flexible framework to organize instructional design into seven components: instructional objectives, content specifications, learner analysis, resource selection, strategy development, and evaluation procedures. Unlike linear procedural models (e.g., ADDIE) or sequential systems models (e.g., Branch, 2009; Dick et al., 2015) that focus on one-stage-at-a-time progress, GEM considers each instructional element as interconnected, dynamically influenced by other instructional elements. Therefore, the objectives selected will influence the development of the strategy; the organization of the content will influence the design of the assessment; and feedback will influence the revisions of the lessons. The interconnected nature of this design represents a systemic view of instructional design that aligns with the principles of constructive alignment and the interdependence of teaching, learning activities, and assessment (Biggs & Tang, 2011). Backward curriculum design views instructional objectives first and then guides the selection of assessment evidence and learning experiences to create coherent decision-making regarding lesson planning (Wiggins & McTighe, 2005).

The purpose of comparing GEM to ADDIE and Dick and Carey is to demonstrate how GEM is better suited than these models for supporting systems thinking and creativity. ADDIE is a systematic instructional design model that can be used to plan instruction; however, many users implement ADDIE in a linear fashion that does not allow for iterative feedback loops necessary to refine learners' systems models and creative products throughout the cycle of explanation, evaluation, and revision (Branch, 2009). Systems thinking instruction requires a series of iterative routines to have learners repeatedly test relational explanations against evidence and revise their representation. Such iterative logic is well-suited to design routines that focus on feedback loops and revision sensitivity, especially when modeling and explaining are a significant part of learning (NGSS Lead States, 2013).

The system's approach from Dick and Carey uses rationalism by using explicit goal analysis, assessment alignment, and formative evaluations to show evidence of instructional design built on measurable outcomes (Dick et al., 2015). On the other hand, GEM has a relatively more flexible and classroom-oriented architecture that focuses on instructional resource choice, groupings, and instructional implementations as interrelated factors, as well as evaluation. This flexibility is especially important in elementary science contexts where multi-representational resources, modeling tools, and feedback procedures need to be adapted to developmental constraints and stay aligned. From a cognitive perspective, this design sensitivity is also consistent with the principles of cognitive load management, where instructional sequence and Scaffolding can impact learners' ability to combine complex information in a manner that is not overly burdensome (Sweller, 2011).

From a systems perspective, the structural logic of GEM mirrors the fundamental principles of systems thinking, namely relational coherence, feedback sensitivity, and integrated wholes (Senge, 1990; Meadows, 2008). Although the literature on systems thinking describes the cognitive attributes of systemic reasoning (Richmond, 1993; Ben-Zvi-Assaraf & Orion, 2005), GEM provides a procedural method by which such reasoning can be embodied in classroom practice. Through linking the objectives of instruction to relational and dynamic reasoning tasks, GEM creates potential for students to develop the patterns of interconnectedness and conceptual integration while engaged in science learning.

GEM's focus on clear objectives and methods for strategy selection will also help us intentionally include higher-order cognitive processes in lesson design. When creativity dimensions such as flexibility, elaboration, and originality are included in objective statements and criteria for assessment, the instructional activities can be structured to support divergent exploration in addition to rigorous analytical inquiry (Henriksen et al., 2016; Beghetto & Kaufman, 2014). Thus, GEM serves not only as a procedural planning tool but also as a cognitive scaffold for supporting generative reasoning and conceptual transformation, provided that instructional routines provide multiple cycles of feedback and revision (Hattie, 2009).

Although there exists considerable theoretical compatibility, research investigating the integration of formal instructional design models within elementary science education is empirically comparatively limited. Studies related to systems thinking typically focus on conceptual frameworks or the outcomes of interventions without describing the specific instructional design structure that facilitates cognitive change (Hmelo-Silver et al., 2017). Similarly, research related to creativity tends to emphasize assessment instruments instead of the underlying design principles that foster creative engagement (Kind & Kind, 2007; Torrance, 1974). This separation illustrates the ongoing schism between the cognitive theory and instructional design practice, and thus requires structured synthesis and conceptual integration.

In the context of the Saudi educational environment, where reform efforts emphasize innovation, analytical reasoning, and student-centered instruction, instructional design models offer practical means for converting national priorities into routine classroom practices (Ministry of Education, 2019). Saudi Vision 2030 also stresses enhancing educational quality, developing curricula, and increasing the capacity of teachers as necessary preconditions for preparing learners to address future challenges (Government of Saudi Arabia, 2016). Therefore, examining GEM using a structured analytical framework addresses a significant knowledge gap at the intersection of instructional design, systems thinking, and creativity research and also offers practical applications for developing and implementing curricula in elementary science classes in Saudi Arabia.

Recent studies using the Gerlach and Ely model in modern science classroom settings are beginning to provide empirical evidence that the model is relevant to the cognitive developmental process of developing thoughtfully structured cognition. The recent study by Alanazi and Khairani (2025) indicated that science students at the sixth grade level showed significant improvement in both their systems thinking abilities and creativity after instruction using modules developed from the GEM model. This suggests that the systemically related structure of GEM may be an effective mediating instructional strategy that enables educators to better align goals, strategies, and assessments with the development of higher-order cognition. These results validate many of the theoretical assertions made earlier about the systemic design logic of GEM.

Positioning the Present Review and Identifying the Research Gap

There are many reasons why systems thinking and creativity do not operate together in science education instructional designs. One reason is that there have been many articles about systems thinking and many articles about creativity, but very little about both being used in science instructional design (Ben-Zvi-Assaraf & Orion, 2005; Assaraf & Orion, 2010; Yoon et al., 2018; Torrance, 1974; Beghetto & Kaufman, 2014; Henriksen et al., 2016). The major reason for this lack of connection is that these two areas of research have developed separately. Cognitive researchers define systems thinking and creativity through various theories and models. However, they rarely describe the instructional design mechanisms that would allow teachers to implement these ideas in the classroom (Hmelo-Silver et al., 2017). On the other hand, instructional designers describe how instructional materials should be designed and delivered but fail to include the higher-order thinking and creative aspects of instruction as interconnected learning outcomes (Reigeluth & Carr-Chellman, 2009). International Standards perspectives support the idea that systems thinking should be viewed as a designed competency supported by explicit learning progression and assessment mechanisms, rather than assuming that it will develop in the classroom through incidental exposure to complex content (National Academies of Sciences, Engineering, and Medicine, 2013).

Another gap is developmental specificity. The upper elementary years, specifically grade 6, are a significant transitional period in children's cognitive development. During this time, abstract thinking, relational integration, and metacognitive regulation develop (English, 2016). Research indicates that intentional instructional design in the upper elementary grades can significantly facilitate the development of systems thinking (Ben-Zvi-Assaraf & Orion, 2010). Similarly, research supports that late elementary years' creativity is linked to continuous engagement in inquiry and problem-solving. Therefore, creativity can be conceptualized as embedded in "learning" and as "mini c" creativity as opposed to merely a divergent production measure (Kaufman & Beghetto, 2009). Although the late elementary years are significant for both systems thinking and creativity, relatively few research studies have investigated the extent to which structured instructional design models can support systems thinking and creative capacities at the same time.

Finally, there is a gap related to the alignment of instructional design with national reform agendas. Policy priorities in Saudi Arabia focus on innovation and higher-order thinking as key strategic educational goals (Ministry of Education, 2019). National transformation initiatives also emphasize improvement of education quality and teacher development (Government of Saudi Arabia, 2016). However, the extent to which these priorities translate into instructional mechanisms within elementary science classrooms has not been extensively studied. Thus, strengthening system-level evaluation and assessment capacity, as shown in current international reviews, shows the importance of designing instructional models that are coherent and aligned with measurable learning outcomes (OECD, 2024).

Although Systems Thinking and Creativity in Science Education have developed rapidly in terms of research during the last ten years, recent Bibliometric and Systematic Mapping Studies still indicate a lack of connection between Cognitive Theory and Design Implementation at the Classroom Level (Budak & Ceyhan, 2024; Bielik et al., 2023). Although the level of Conceptual Sophistication has improved, there are very few empirical or design-based research studies that provide evidence to determine how Formal Instructional Design Models Operationalize Both Constructs Simultaneously in Elementary Settings. Additionally, Contemporary Research in Instructional Design is calling for Mechanism-Based Explanations to Elucidate How Specific Components of Design Activate Cognitive Processes Rather Than Merely Describing Procedural Steps (Paré et al., 2015; Snyder, 2019). For these reasons, this study is justified, not only by the Separation Between Systems Thinking and Creativity, But Also by the Lack of Theoretically Integrated Instructional Mediation Frameworks That Can Align Design Architecture with Higher-Order Cognitive Outcomes in Elementary Science Contexts.

These three gaps are related and require an analytical approach that situates cognitive constructs within formal instructional design. This paper addresses these needs by reviewing the theoretical and empirical bases for using the Gerlach and Ely instructional model within elementary science education. The specific purpose of this paper is to explore how GEM-based instructional modules could serve as mediating structures that link objectives, content sequencing, instructional strategies, and evaluation processes to promote systems thinking and creative capacities in sixth-grade students in Saudi Arabia. The paper will synthesize instructional design theory, systems thinking literature, and creativity research within a single framework to (1) illustrate the conceptual connections between systems thinking and creativity, (2) identify methodological and contextual limitations in previous studies, and (3) outline a theoretically grounded model for future empirical testing.

Recent reviews have shown that there is a significant difference in how cognitive theory is used and implemented at a classroom level with respect to systems-based science education around the world (Budak & Ceyhan, 2024; Bielik et al., 2023). Although there is an abundance of research on systems thinking frameworks and their conceptual development, there are still very few studies showing the transition from these conceptual frameworks to formal instructional designs. The need to integrate and analyze instructional design models is reinforced by the continued lack of studies linking cognitive constructs and classroom measures.

Conceptual Tensions in the Literature

Although there is a great deal of agreement in the literature that both systems thinking and creativity should be major product knowledge areas of contemporary science education, there remains a great deal of conceptual debate regarding the extent to which they can be incorporated into design-based architectures of classroom design.

First, systems thinking frameworks have provided sophisticated ways of describing what it means to reason at a systems level; however, the frameworks rarely address the issue of how one might embed such reasoning in reliable ways into the sequence of lessons, activities, and assessments in classrooms. The increasing body of evidence regarding the "design-implementation" gap in the literature in science education design has identified that systems thinking frameworks do not always translate into effective classroom design practices, and thus require design and learning progression guidelines to be developed into teachable and assessable competencies (Gilissen et al., 2020). At the same time, crosscutting concepts, including "systems and system models," are identified as foundational by all three standards frameworks (NGSS Lead States, 2013; National Academies of Sciences, Engineering, and Medicine, 2013); however, the standards frameworks note that such crosscutting concepts will be taken up meaningfully by students only when there exists coherent and well-designed instructional design and carefully planned and sequenced learning experiences, and not simply as a result of policy endorsement (National Research Council, 2011).

Second, much of the educational creativity literature in education has been influenced by psychometrics, particularly the use of convergent and divergent thinking measures, which allow for comparisons across different contexts and conditions. However, reviews of creativity in the school science setting reveal a tension between measuring and promoting creativity and developing the design of instruction that supports the development of creativity as a component of scientifically specific scientific practices.

As a result, creativity is frequently treated as an external measure of student performance rather than as a skill that can be designed into the objectives, tasks, and evaluation criteria of instruction (Kind & Kind, 2007). Perspectives on creativity in educational psychology also note that the advancement of the field of creativity in education depends upon greater conceptual clarity and better alignment between the conceptualization of creativity, its measurement, and its intended educational purposes (Plucker et al., 2004; Runco & Jaeger, 2012). Additionally, classroom-focused work emphasizes that creative performance is context-dependent and affected by factors such as classroom norms, feedback processes, and the availability of opportunities for students to take risks in ways that can lead to productive learning outcomes (Beghetto & Kaufman, 2014).

Finally, many instructional design models offer strong procedural advice for the planning and evaluation of instruction. Still, they are rarely formulated as cognitive mediation architectures that map instructional design decisions onto cognitive processes such as cognitive load regulation, schema activation, iterative internalization of feedback, and conceptual restructuring. Therefore, there is a structural mismatch in the relationship between cognitive theories and instructional design models: cognitive theories describe how learning occurs, while instructional design models describe how instruction is organized, with little explicit linkages made between the components of instructional design and the cognitive mechanisms underlying the design decisions (Sweller, 2011). Moreover, evidence from learning research indicates that poorly guided learning designs can impede both the efficiency and the conceptual clarity of learning, especially for complex tasks, and reinforce the importance of structurally guiding learning design and instructional architecture to promote both developmental appropriateness and intentional cognitive activation (Mayer, 2004).

In total, the collective evidence of the four gaps suggests that the primary obstacle to implementing the theoretical foundations of systems thinking and creativity in classroom design is not a lack of conceptual clarity, but the absence of design-based instructional architectures that translate these constructs into design-based instructional design sequences, feedback structures, and assessment indicators. So, addressing this gap means we should view instructional design not just as procedural planning, but as a way to support cognitive processes in classroom practice.

Methodology of the Review (Strengthened Version)

Review Design

This study uses a structured analytical review to compile theoretical and empirical knowledge at the interface of instructional design, systems thinking, and creative capabilities in elementary school science education. This methodology is congruent with both integrative and theory generation review methodologies, each of which is designed to assist in reducing conceptual fragmentation, identifying cross-study patterns, and developing coherent analytical frameworks to guide future empirical validations (Torraco, 2005; Snyder, 2019). Consistent with the logic underlying integrative reviews, this study seeks to produce new conceptual knowledge from existing studies through systematic comparative analysis, interpretive analysis, and theoretical integration of studies (Whittemore & Knafl, 2005) instead of simply describing them.

This study differs from meta-analytic reviews, which combine statistical estimates of effect size, in its emphasis on integrating concepts, synthesizing themes, and creating analytical maps of constructs across related literature (Grant & Booth, 2009). This study's objective is not to provide an estimate of the overall effectiveness of interventions based upon effect size, but rather to analyze how higher-level constructs, specifically systems thinking and creative capacity, can be systematically integrated into the formal instructional design architecture. Therefore, the study prioritizes the development of conceptually cohesive frameworks, cross-domain comparisons, and the development of frameworks for understanding over quantitatively synthesizing evidence. This position is consistent with the guidance provided to distinguish review types by purpose and product output, and indicates that when the primary objective is to expand or consolidate foundational conceptual frameworks, then integrative and theory-generation reviews are preferred over those that seek to estimate pooled effects (Paré et al., 2015).

We used a structured analytical review to investigate how the Gerlach and Ely Instructional Model could serve as a mediating instructional framework linking cognitive processes to learning outcomes. The review also intended to provide an efficient process for translating higher-level concepts into actual classroom settings as well as to develop a recommended research methodology that used theoretical/conceptual relationships as the basis of reviews rather than simply reviewing individual authors (Watson & Webster, 2002).

Literature Search Strategy

To achieve methodological transparency and rigorous scholarship, literature was identified via targeted database searches on the major index platforms (Scopus, Web of Science, ERIC, and Google Scholar) as they represent the most comprehensive peer-review coverage of education, instructional design, and learning sciences; moreover, multi-database searching is highly recommended to minimize the risk of retrieval bias and enhance coverage in evidence syntheses (Tranfield et al., 2003).

These targeted searches focused on peer-reviewed journals, review articles, theory-based publications, and foundational texts related to instructional design, systems thinking, and creative ability in educational environments. Boolean operators were utilized to combine keywords based on the conceptual scope of this review, such as:

- “Gerlach and Ely” AND “instructional design.”
- “Systems thinking” AND “Science Education.”
- “Systems Thinking” AND “Elementary School.”
- “Creativity” AND “Science Learning.”
- “Creative Abilities” AND “STEM Education.”
- “Instructional Design” AND “Higher Order Thinking.”

In general, the primary focus of the search process was to target recent publications since 1990, while preserving seminal theoretical work foundational to the concepts under study (i.e., Gerlach & Ely, 1980; Torrance, 1974; Senge, 1990; Meadows, 2008). To support methodological traceability, the search and screening process was documented in accordance with established reporting standards for evidence synthesis. However, it is acknowledged that this review is not positioned as an exhaustive systematic review in accordance with PRISMA (Page et al., 2021).

For scoping-oriented mapping, the logical approach to identifying, screening, and mapping the evidence was informed by well-established scoping review frameworks and updates, which outline the distinctions between evidence-mapping approaches and effect estimation reviews (Arksey & O'Malley, 2005; Levac et al., 2010; Peters et al., 2020; Tricco et al., 2018).
A large number of studies were initially returned as part of the search results. Following title and abstract screening for conceptual relevance, full-text examinations were conducted of the shortlisted articles. Studies specifically focused on systems thinking, creativity in science education, or instructional design frameworks designed for K-12 settings were ultimately included in the analytical synthesis. The screening rationale reflects established guidance that eligibility decisions should be based upon clearly defined conceptual relevance to the review's analytical purpose and framework-building objectives (Okoli & Schabram, 2010).

Inclusion and Exclusion Criteria

The explicit use of inclusion/exclusion criteria provided both a means to ensure analytical clarity and to maintain thematic focus. In addition to the clear decision-making process for constructing an interpretive body of evidence required by integrative review (Torraco, 2005; Snyder, 2019), studies were selected based upon their content as follows:

Selected Studies

Were included in the study if they:

1. Addressed the development of systems thinking in science/STEM education contexts.
2. Examined the creative processes, including the measures of divergent thinking or generative reasoning, in educational settings.
3. Included discussions of structured instructional design models relevant to elementary learning environments.
4. Focused on elementary or upper-elementary students in studies that report empirical data.
5. Were published in peer-reviewed journals or were considered seminal works in recognized theories.

Excluded Studies

Were excluded from this study if they:

• Addressed only higher education contexts with no clear basis for pedagogical transferability to elementary science education.
• Examined either creativity or systems thinking in non-educational areas without relevance to classroom instruction.
• Did not include conceptual relevance to instructional structure or design architecture.
• Were not scholarly publications or did not clearly outline methods used.

Using these criteria as filters resulted in an analysis corpus that was conceptually aligned with the integrative review's objective and reduced potential conceptual drift. Consistent with recommendations that the validity of a review is dependent on aligning the research purpose, inclusion criteria, and synthesis strategies (Whittemore & Knafl, 2005; Paré et al., 2015) to minimize error, especially for theory-building reviews, where the primary quality criterion is conceptual coherence, the use of specific inclusion and exclusion criteria are integral to ensuring the validity of this review.

Analytical Procedure

The Review utilized a multi-stage Analytical Synthesis Process as recommended by the Integrative Review methodology literature (Torraco, 2005; Snyder, 2019), and further enhanced its Analytical Rigor by utilizing both Concept-Centric Mapping and Transparent Theme Development Methods as outlined in the qualitative and narrative synthesis literature within Evidence-Based Reviews (Popay et al., 2006).

Stage 1: Conceptual Mapping

All of the key constructs identified in the selected studies, such as Instructional Alignment, Relational Reasoning, Dynamic Reasoning, Flexibility, Elaboration, and Originality, were identified and mapped across all of the selected studies. The definitions, theoretical propositions, and the reported results of each study were compared to determine areas of convergence and divergence. In this conceptual organization, the selected studies were

grouped by construct and relationship as recommended by Webster and Watson (2002), as opposed to being listed sequentially based on publication.
Stage 2: Thematic Categorization
The selected studies were categorized into three thematic clusters:
• Systems Thinking Frameworks in Science Education
• Creativity Models and Divergent Thinking Research
• Applications of Instructional Design in K-12 Contexts

Organizing the selected studies into these thematic categories allowed for structured cross-domain comparisons to be made and facilitated the identification of conceptual overlap among the selected studies. The thematic categories were developed using a transparent coding-to-themes approach consistent with the widely used thematic analysis methods (Braun & Clarke, 2006) and supported by methods developed specifically for synthesizing qualitative evidence in systematic reviews where analytical themes are generated from coded results across studies (Thomas & Harden, 2008).

Stage 3: Integrative Synthesis and Framework Development
The selected studies were analyzed to identify the intersection points between cognitive constructs and instructional structures. We examined the connections to see how the principles of alignment in the Gerlach and Ely model could serve as bridges to incorporate systems thinking and creativity in science instruction. The goal of the synthesis was to develop an integrative framework that would reflect the common conceptual relations found throughout the selected studies, consistent with the expectations for integrative reviews to produce a framework that extends existing theory or proposes a structural model for future testing (Torraco, 2005). As a result of the insights gained from this synthesis, an integrative conceptual framework was developed and is presented in Figure 3.

Methodological Positioning and Scope
To be clear, this review does not assert an exhaustive systematic overview (in the strict PRISMA sense) (Page et al., 2021), but rather a structured analytical synthesis that identifies theoretical fragmentation and provides a theoretically grounded instructional framework to be empirically validated. This methodology is consistent with established categorizations of reviews, including those that distinguish between integrative and theory-building reviews versus exhaustive systematic reviews, especially when the primary goal is to synthesize concepts instead of estimate effects (Grant & Booth, 2009; Snyder, 2019).

The use of a hybrid methodology (with both methodological rigor and theoretical ambition) allows for a balance of transparency as well as theoretical ambitions. The review has used explicitly articulated search strategies, inclusion criteria, and analytical steps to increase methodological rigor while maintaining alignment with the primary objective of the review: developing a theoretically integrated model that combines instructional design, systems thinking, and creative development in elementary science education. Through these methodologies, the review followed existing evidence synthesis guidelines to provide clarity of review purpose, provide a mechanism for traceability of decision-making processes, and provide a relationship between the evidence synthesized and the claims made by the proposed framework (Tranfield et al., 2003; Whittemore & Knafl, 2005).

Analytical Synthesis of the Theoretical and Methodological Landscape

Theoretical Fragmentation in the Literature

In terms of theoretical mapping as depicted in Table 1, there is an identifiable structural separation among three distinct areas of research: Systems Thinking Theory, Creativity Research, and Instructional Design Models. Each area has been extensively developed individually, and while its integration with Elementary Science Education has some historical precedent, this combination remains relatively rare.

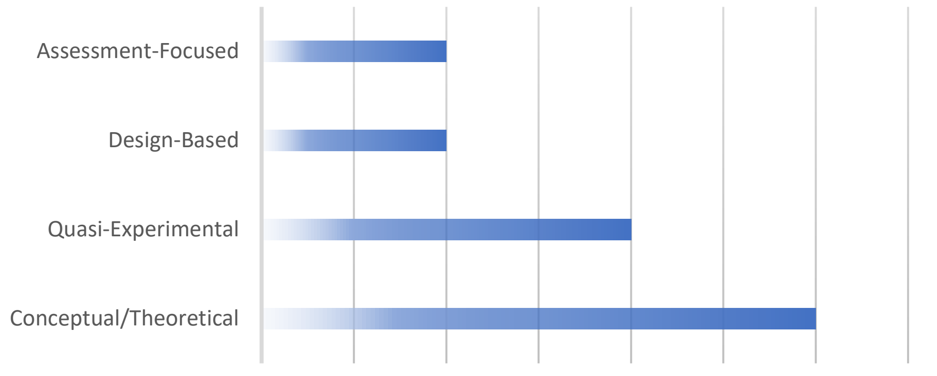
The Systems Thinking Literature (Ben-Zvi-Assaraf & Orion, 2005, 2010), specifically the Hierarchical and Relational Systems Frameworks, provides detailed descriptions of the cognitive processes used by students when identifying parts, recognizing relationships among those parts, and understanding the dynamics of systems. Also, numerous system theory books (Senge, 1990; Meadows, 2008; Richmond, 1993) discuss interdependence, feedback loops, and holistic reasoning at the systems level. While the system theory literature provides a wealth of information about systems thinking, it primarily outlines what constitutes systems thinking without providing a clear method for embedding systems thinking into instructional practices.

Similarly, the Creativity Literature presents a consistent pattern of describing cognitive processes associated with creativity. Torrance's (1974) Operationalization of Flexibility, Elaboration, and Originality through Standardized Assessments provides quantifiable measures of creative performance. Like systems thinking literature, however, creativity literature typically focuses on Assessment and Cognitive Description rather than Structured Pedagogical Implementation.

In contrast, the Gerlach and Ely Model (1980) provides an Instructional Architecture for Organizing Objectives, Content, Strategies, and Evaluation Procedurally. While the model was originally designed to serve as a general-purpose instructional design model, it does not include any specific systems thinking or creativity constructs. As demonstrated quantitatively in Figure 1, the Systems-Oriented Theories represent the primary theoretical basis for the literature, and the number of Explicit Integrative Instructional Designs remains significantly lower. This disparity indicates that while the literature provides extensive conceptual definitions of systems thinking and creativity, there are few Mechanisms for Joint Cognitive Development of both Systems Thinking and Creativity within Elementary Science Classrooms.

Table 1
Analytical Mapping of Core Theoretical Foundations Underpinning GEM, Systems Thinking, and Creativity

Study	**Theoretical Focus**	**Core Concepts**	**Relevance to GEM**	**Implications for Systems Thinking**	**Implications for Creativity**
Gerlach & Ely (1980).	Instructional Design Model	Objectives alignment, content organization, strategy selection, evaluation	Provides a structured instructional framework	Supports systemic alignment between instructional components	Enables structured integration of creativity into objectives and assessment
Ben-Zvi-Assaraf & Orion (2005).	Systems Thinking Hierarchical Model	Identification of components, relationships, and dynamic cycles	Can be operationalized through structured instructional sequencing	Develops relational and dynamic reasoning	Encourages integrative conceptual restructuring
Ben-Zvi-Assaraf & Orion (2010).	Systems Thinking at the Elementary Level	Progressive development of systemic reasoning	Suggests the need for scaffolded instructional models	Demonstrates elementary-level feasibility	Indirect support via cognitive expansion
Meadows (2008)	Systems Theory	Feedback loops, interconnections, and dynamic behavior	Aligns with the interconnected design logic of GEM	Strengthens holistic reasoning	Promotes adaptive thinking patterns
Richmond (1993)	Systems Thinking Skills	Dynamic thinking, closed-loop thinking	Supports structured learning sequences	Encourages recognition of systemic interdependence	Enhances flexible cognitive transitions
Senge (1990)	Learning Organizations & Systems Thinking	Interconnected mental models	Reinforces systemic alignment in design	Promotes integrative cognition	Encourages generative thinking
Torrance (1974)	Creativity Theory & Assessment	Flexibility, elaboration, originality	Can be embedded within instructional objectives	Enhances idea generation within system contexts	Direct operationalization of creativity dimensions



	Conceptual/Theoretical	Quasi-Experimental	Design-Based	Assessment-Focused
Frequency	3	2	1	1

Figure 1: Distribution of Theoretical Foundations

Methodological Imbalance and the Need for Structured Integration

The data presented in Table 2 demonstrates even more the fragmentation in the literature concerning systems thinking. Systemic thinking can be developed when instruction scaffolds are employed intentionally, as demonstrated by Ben-Zvi-Assaraf and Orion's (2005) and (2010) empirical studies concerning the structural implementation of systems thinking. However, it appears that a large portion of the foundational literature for both systems thinking and creativity remains theoretical or focuses on assessment (Torrance, 1974; Meadows, 2008).

The data in Figure 2 illustrate that conceptual/theoretical contributions comprise a very significant segment of the base of knowledge, while empirically based, integrated instructional design applications for systems thinking and creativity are quite limited. In other words, the literature clearly provides conceptual clarity with respect to systems thinking and creativity; however, there has been very little empirical research that operationally defines the development of systems thinking and creativity through a formally defined model of instructional design.

Additionally, the majority of quasi-experimental studies have examined either systems thinking or creativity individually as opposed to examining the simultaneous development of both concepts in an integrated instructional model. The separate examination of systems thinking and creativity is especially important at the elementary school level, since cognitive scaffolding must be developmentally appropriate and pedagogically consistent (Ben-Zvi-Assaraf & Orion, 2010).

Together, the data from Tables 1 and 2 indicate that the primary gap in the literature is not definitional, but integrative. In particular, there has been a very limited amount of analytical study regarding how the use of structured instructional models, such as the Gerlach and Ely model (Gerlach & Ely, 1989), would function as mediators that translate students' systemic thinking abilities and creative capacities into classroom practices in elementary school science education.

Table 2
Methodological Patterns in Research on Systems Thinking and Creativity in Science Education

Study	**Target Population**	**Research Design**	**Measurement Tools**	**Intervention Type**	**Key Methodological Insight**
Ben-Zvi-Assaraf & Orion (2005).	Secondary students	Design-based intervention	Open-ended tasks, conceptual analysis	Curriculum-based intervention	Systems thinking develops progressively when embedded in structured instructional sequences.
Ben-Zvi-Assaraf & Orion (2010).	Elementary students	Longitudinal quasi-experimental	Performance-based assessments	Structured instructional activities	Systems thinking can be fostered at the elementary level with scaffolding
Richmond (1993)	Conceptual/theoretical	Theoretical analysis	Conceptual taxonomy	Not intervention-based	Emphasizes dynamic reasoning components but lacks classroom operationalization
Meadows (2008)	Conceptual/theoretical	Systems analysis	Conceptual framework	Not classroom-based	Provides systemic logic but not pedagogical procedures
Torrance (1974)	School students	Standardized testing framework	TTCT (Flexibility, Elaboration, Originality)	Assessment-focused	Creativity is measurable but requires a structured learning context
Senge (1990)	Organizational learning	Theoretical model	Conceptual frameworks	Not classroom-based	Systems thinking framed broadly without instructional design mapping
Gerlach & Ely (1980).	General education	Instructional design framework	Structured planning & evaluation	Model-based design	Provides procedural alignment but is not tested directly for systems thinking or creativity outcomes

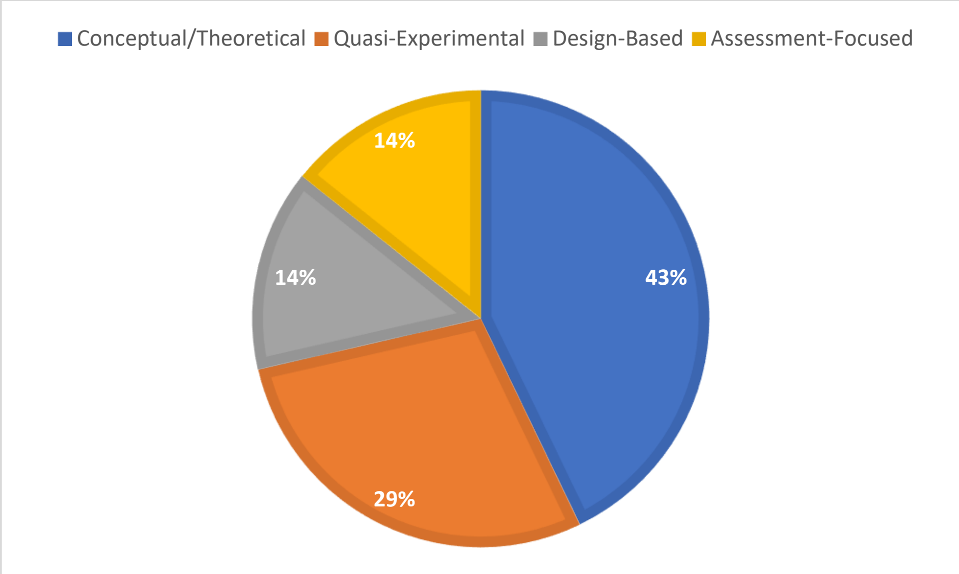


Figure 2: Distribution of Research Designs

Integrative Conceptual Framework
Positioning GEM as a Mediating Instructional Structure

Structural Alignment between GEM and Systems Thinking
The Gerlach and Ely instructional model (Gerlach & Ely, 1980) has been structured so that there is a logical relationship between instructional objectives, content specifications, strategy selection, resource allocation, and evaluation. While the Gerlach and Ely model was developed as an instructional design model, it follows some of the same principles that describe Systems Thinking Theory.

Systems thinking refers to viewing a system or process as composed of components, identifying relationships, understanding how feedback affects processes, and viewing a system as a whole (Ben-Zvi-Assaraf & Orion, 2005; Meadows, 2008). So, the instructional elements of GEM (objectives, strategy, content, resources, assessment/evaluation) show a connected, systemic approach. Thus, objectives influence which strategies are selected for implementation, content organization influences how assessment occurs, and assessment/evaluation informs how revisions occur. This interconnectedness represents a micro-system of instruction within the larger instructional process.

As a teacher, having clearly defined and internally coherent instructional elements can provide a structure from which students can develop relational thinking skills. When learning experiences are sequentially aligned, students have a greater likelihood of seeing relationships between concepts rather than merely memorizing discrete pieces of information.

Therefore, while the Systems Thinking literature describes cognitive characteristics, GEM provides a procedural structure through which these characteristics can be embedded into everyday teaching practices.

Cognitive Mediation Mechanisms Activated by GEM

To go beyond stating that GEM is simply a generalized planning model, this framework specifies four cognitive mediation mechanisms that instructional design decisions can follow to lead to systems thinking and creativity results.

(1) Cognitive Load Regulation.

The purposeful focus of GEM on clear goal setting, content organization, and strategic planning can reduce extraneous cognitive load by providing learners with sequential tasks and representations. The theory of cognitive load (CLT) suggests that instructional success is based on the regulation of limited working memory resources, particularly when learners need to combine many interacting variables (i.e., as in systems thinking), to reason about dynamic systems (Sweller, 2011). Therefore, how we structure sequencing and provide learner access to information is a design choice that supports cognitive capacity for relational and dynamic reasoning in complex science subjects.

(2) Relational Schema Activation.

Systems phenomena are often poorly understood due to the fact that learners tend to utilize simplified, direct-causal schemas that do not reflect the emergent, multi-causal nature of systems. Research in conceptual change has shown that learners' misconceptions regarding systems will continue to exist when they use an inappropriate explanatory schema and will change only when an appropriate relational schema is activated, one that is reflective of the emergent causal structures (Chi et al., 2012). GEM's objectives, task prompts, and assessment criteria can be intentionally designed to cue relational and feedback-based explanatory schemas rather than single variable causal narrative explanations.

(3) Iterative Feedback Internalization.

GEM's evaluation-revision logic can be implemented as a series of iterative formative feedback cycles so that learners may continually compare their performance with their intended goals as they develop their system models and creative products. Studies have shown that learning gains are contingent upon the quality, timing, and task focus of feedback and that feedback loops can either facilitate or hinder learning, depending on the instructional design (Hattie & Timperley, 2007). Thus, embedding iterative formative assessments within GEM enables learners to internally realize the expectations for systemic explanation and creative elaboration (Wiliam, 2011).

(4) Conceptual Restructuring Loops.

The combination of a structured sequence, relational schema cues, and iterative feedback creates conditions for learners to experience conceptual restructuring, where learners restructure prior knowledge into more cohesive system models. This is particularly pertinent for systems thinking outcomes, since it requires learners to transition from fragmented causal accounts to a representation of interdependencies and delays. Thus, GEM's systemic alignment is a designed "restructuring loop" that allows learners to stabilize their new conceptual organizations of the subject matter over time (Chi et al., 2012; Gilissen et al., 2020).

By identifying these mechanisms, GEM is reframed as an instructional mediating architecture that connects design elements (objectives, sequencing, strategies, and evaluations) to cognitive processes that enable learners to grow in both systems thinking and reasoning abilities and creative capacities.

Cognitive Mediation Mechanisms Linking GEM to Creative Capacities

Creativity is defined by Torrance (1974) as the ability to flexibly generate many ideas in elaborated ways, which are new. Thus, it is appropriate that classroom environments for developing creativity will have some amount of structural elements, as well as, as much as possible, openness in terms of the cognitive processes of students.

GEM provides a structured environment that allows the teacher to define the goals of instruction and to identify specific criteria to be used in assessing the degree to which creative tasks were performed, i.e., clearly defined objectives. Additionally, GEM's content sequencing is also designed to prevent excessive cognitive load on the student. In addition to providing a structured format, GEM also includes a variety of different approaches for structuring instruction to provide students with a variety of different approaches to explore in their learning.

The assessment tools provided by GEM are designed to evaluate performance based upon the same three dimensions of creativity identified by Torrance (1974). Thus, the use of assessment tools in conjunction with the instructional strategies employed in GEM would be expected to promote both adaptive and generative thinking.

Systems thinking (Richmond, 1993) and creative problem solving are related cognitively in that systems thinking deals with understanding the relationships between parts of a system and how they interact to produce emergent properties. Creative problem solving, on the other hand, involves finding novel or creative ways to relate the parts of a system. Since GEM can align all of its components to promote both systemic thinking and creative problem solving, it could potentially act as a mediator to facilitate the development of both types of thinking simultaneously.

There has been little research into instructional design models that address the relationship between systemic thinking and creative problem solving. As such, there is significant theoretical importance to exploring GEM not just as an instructional model to guide the delivery of instruction, but rather as a model that could serve as a cognitive scaffolding tool to integrate both types of thinking.

Table 3
Integrative Alignment Model

Study Element	GEM Component	Systems Thinking Dimension	Creativity Dimension	Pedagogical Function
Objective Specification	Clear learning goals	Identification of system components	Originality targets	Defines cognitive expectations
Content Organization	Structured sequencing	Recognition of relationships	Elaboration	Supports conceptual expansion
Instructional Strategy	Interactive activities	Dynamic reasoning	Flexibility	Encourages perspective shifting
Resource Selection	Multi-modal inputs	Multi-level system representation	Idea fluency	Stimulates generative exploration
Evaluation & Feedback	Continuous assessment	Feedback loop understanding	Creative refinement	Reinforces adaptive reasoning

To address the identified theoretical and methodological fragmentation, the present review proposes an integrative conceptual model positioning GEM as a mediating instructional structure linking cognitive processes to learning outcomes. The model synthesizes insights from instructional design theory, systems thinking frameworks, and creativity research into a unified structure.

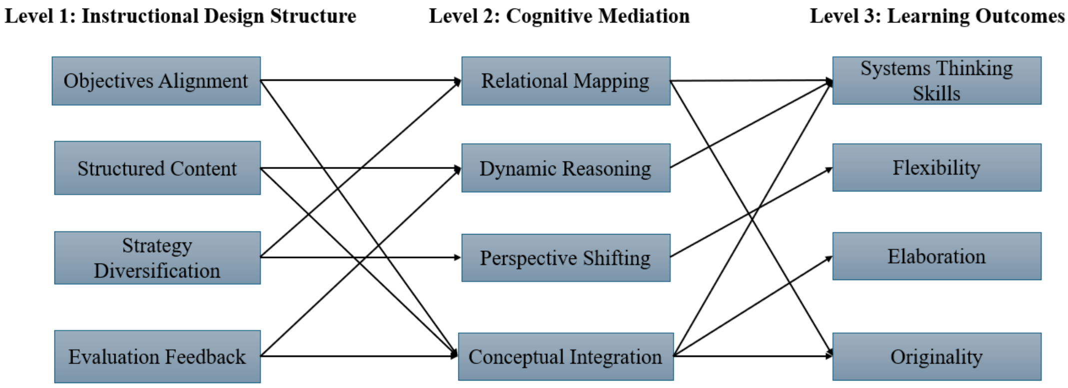


Figure 3. Integrative Conceptual Model Linking GEM to Systems Thinking and Creative Capacities

The Model (as shown in Figure 3) represents the elements of GEM as structural antecedent factors that can stimulate distinct types of cognitive mediating processes. Each type of cognitive process then impacts both Systems Thinking and Creative Capacities to differing extents via separate paths. Importantly, systems thinking is viewed as an aggregate of multiple cognitive processes and is not represented as having a singular effect, due to the fluid nature of cognition.

Theoretical Contribution
This review develops theory at the convergence of instructional design, systems thinking, and creativity through three interconnected contributions.
The first contribution provides a new perspective on instructional design as a cognitive mediation architecture.

Instead of treating instructional design as a procedural planning sequence of instructional materials, the proposed framework describes how design elements are mediated to modulate cognitive load, stimulate relational schema activation, and establish conceptual restructuring via feedback mechanisms (Chi et al., 2012; Sweller, 2011; Hattie & Timperley, 2007). This shows GEM as a way to explain the rationale and processes of how design decisions support higher-level thinking, not just a way to arrange instruction.

The second contribution offers a new understanding of systems thinking as an instructionally-activable construct.
While systems thinking has been identified as a desirable competency, there continues to be inconsistent enactments of systems thinking in classrooms. By combining design principles with cognitive mechanisms, this review situates systems thinking as an intended outcome that can be intentionally evoked through aligned objectives, sequenced representations of concepts, and iterative evaluations of student work rather than assumed to occur indirectly (National Research Council, 2012; Gilissen et al., 2020).

The third contribution integrates creativity into structural alignment logic.
In many cases, creativity in school science is treated as a separate entity from the instructional conditions that support it. Drawing on scholarship related to creativity in classroom settings, and reviewing literature examining the role of creativity in school science, this framework incorporates indicators of creativity (flexibility, elaboration, originality) into objectives, tasks, and formative assessments to shift creativity from being an external test of a trait to a performance capability supported by design (Beghetto & Kaufman, 2014; Wiliam, 2011; Kind & Kind, 2007).

Together, these contributions address fragmentation in cognitive theory and instructional practices by providing a cohesive, mechanism-based explanation of how an instructional design model may simultaneously support the development of systemic reasoning and creative capacities in elementary science learning.

Practical Implications for Elementary Science Education in the Saudi Context
The proposed system thinking framework has some practical uses in addition to its theoretical applications; these practical uses will help guide educators in their teaching practices by providing educators with a tool to assist them in developing curriculum and utilizing this curriculum in the classroom. Specifically, this framework will help Saudi education reformers, who are increasingly emphasizing thinking skills and student-centeredness in their curriculum.

Specifically, first, GEM's Alignment Principle allows educators to clearly develop ways to incorporate systems thinking into their lesson plans. By identifying and defining relational and dynamic reasoning as specific, measurable learning outcomes, educators can then assess those learning outcomes and adjust their assessments to reflect those defined learning outcomes. Second, through the Strategy Diversification Principle of GEM, educators have the opportunity to create and use inquiry based instruction, group problem solving, and multiple representations of learning materials to help students to view the world from different perspectives and understand how all things relate to each other; this will enhance both the student's understanding of systems and encourage creativity in the student population of Grade 6.

Third, educators can structure their feedback to students to foster both dynamic reasoning and conceptual integration. The use of feedback that identifies the relationship between scientific concepts will provide the student with the ability to recognize the interdependency between parts of a natural system; this will be critical in developing a student's ability to think systemically (Ben-Zvi-Assaraf & Orion, 2010).

In the Saudi elementary classrooms where there is significant structure involved in curriculum development, using an instructional model that utilizes cognitive mediation may help to achieve the country's educational goals of higher-order thinking and innovation. This framework also does not call for radical changes in curriculum development; instead, it will allow educators to reorient their current curriculum development toward cognitive alignment and integration.

Boundary Conditions and Implementation Constraints

The theoretical coherence of the proposed GEM-based integrated science teaching approach is subject to several boundary conditions that will influence the quality of the integration in elementary science classrooms.

Boundary condition 1, resource availability, could affect the feasibility of implementing this method. As with many approaches to systems thinking instruction, multiple representation types (e.g., modeling artifacts, conceptual representations, and iterative revision support) are typically used to make system structures both visible and revisable. The availability of resources, particularly those used as models or modeling artifacts, will likely limit the number of different representations available to students and thus limit their ability to see and revise the structure of a system (National Research Council, 2012).

Boundary Condition 2, Teacher Pedagogical Content Knowledge (PCK) and Design Competence, could also affect outcomes. Teachers need to translate design principles into classroom routines if they want to implement an instructional strategy like this one that is aligned to educational goals, that encourages relational reasoning, and that involves formative feedback loops. If teachers do not have sufficient professional development to assist them in translating design principles into classroom routines, then the model may be implemented in a procedural lesson plan format instead of as a mechanisms-based mediation structure (Wiliam, 2011).

Boundary Condition 3, Classroom Assessment Culture, will also influence how long students will be able to sustain creative thought and systems thinking. Studies on feedback indicate that student learning is enhanced when the feedback given to students is focused on the task at hand and is part of a cycle of improvement rather than just a final evaluation (Hattie & Timperley, 2007). When there are classroom assessment cultures that emphasize single-correct answers and high-stakes grading, then students will have fewer opportunities to engage in productive risk-taking, model revision, and creative elaboration of ideas (Beghetto & Kaufman, 2014; Kind & Kind, 2007).

By recognizing these boundary conditions, we can improve the explanatory power of the framework and provide a basis for designing studies to test the effectiveness of the framework empirically by providing specific contextually related moderating variables to examine the impact of the framework rather than examining it as though it has equal effectiveness across all contexts.

Directions for Future Research

The Integrative Model, as proposed by this review, has a number of potential avenues for empirical study.

First, quasi-experimental studies may assess the extent to which the GEM-based instructional module(s) result in measurable increases in systems thinking skills and creative abilities among sixth-grade students. For example, studies of this nature could utilize previously validated hierarchical frameworks (Ben-Zvi-Assaraf & Orion, 2005) to measure systems thinking and the dimensions of flexibility, elaboration, and originality (Torrance, 1974) to measure creativity.

Second, future studies may assess the mediating influence of cognitive processes, such as relational mapping and conceptual integration, via Structural Equation Modeling (SEM). Empirically testing the pathways of mediation would provide further support for the theoretical model as presented here.

Third, longitudinal research designs may be employed to assess whether students who are exposed to systematic science instruction at an earlier age will continue to be engaged in the process of learning science throughout their academic career. Because the development of systems thinking is considered to be a developmental process (Ben-Zvi-Assaraf & Orion, 2010), extended studies assessing the effects of interventions may offer a wealth of information.

Fourth, comparative studies across different educational environments could assess the adaptability of the GEM-based integrative model in educational environments outside of those in Saudi Arabia. This would contribute to cross-cultural research in science education.

Limitations of the Review

This article outlines the integration of a large number of theoretical contributions and empirical research findings to create an overall conceptual framework that describes the role of emotional intelligence in elementary science teaching in the Kingdom of Saudi Arabia (KSA). However, there are also some limitations in the analysis of the present study.

Firstly, the review was based largely upon the primary theoretical foundations and selected empirical studies that fit into the framework of the PhD project, rather than being a systematic search of existing studies using meta-analysis.

Although this structured analytical approach improves conceptual clarity, it cannot guarantee that the review included all relevant studies.

Secondly, the model presented in this study is still at a conceptual level and has not yet been validated or supported by empirical evidence collected from elementary science classrooms. The mediation pathways described in the framework will have to be validated through experimental and quasi-experimental research methods.

Thirdly, as this study is focused on elementary education in KSA and thus theoretically justified, the immediate transferability of implications to other educational systems may depend on the extent to which they can be adapted to different contexts.
By recognizing these limitations, we ensure that our methodology is transparent and provide a basis for validating our research in the future.

Conclusion

This study sought to bring together fragmented conceptual and methodological approaches in the study of systems thinking and creative capacities in elementary science education.
By providing the Gerlach and Ely Instructional Model as a mediating structural framework, this paper developed an integrated view that connected instructional alignment, cognitive processes, and learning outcomes.

The analysis demonstrated that systems thinking and creativity do not have to be viewed as separate instructional objectives. When instructional components are well-aligned, they can elicit relational, dynamic, and integrative cognitive processes that support systemic reasoning and creative expansion.

Therefore, the proposed conceptual model will provide a theoretical basis for a practical framework for supporting higher-order thinking in elementary science education. However, empirical validation is needed before the framework can be utilized. It will also support ongoing work to improve thinking-oriented instruction in the Saudi educational system and other contexts.

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