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Research Article

Cultivating systems thinking through visible thinking routines: Pedagogical and leadership insights from an exploratory classroom study

Erkan Bozkurt

Uşak University, Faculty of Education, Uşak, Türkiye (ORCID: 0000-0002-5548-0385)

This study explores how systems thinking–oriented thinking routines can be integrated into middle school social studies instruction and how such practices are experienced by students and teachers. Framed as an exploratory, classroom-based inquiry, the study examines the implementation of visible thinking routines designed to support students' engagement with complex and interconnected social phenomena. The study was conducted over an eight-week period with fifth-grade students in a public middle school. Data were collected through a combination of pre- and post-intervention descriptive performance measures, student written reflections, and a semi-structured teacher interview, reflecting an exploratory mixed-methods approach. Quantitative data were analyzed descriptively, while qualitative data were examined using thematic analysis to capture patterns in cognitive engagement, affective responses, and instructional processes. The findings suggest that thinking routines supported students in organizing their ideas, recognizing relationships among system elements, and reflecting on their own reasoning processes. Students also reported positive affective experiences, including increased engagement and enjoyment, particularly as they became more familiar with open-ended and dialogic learning activities. From the teacher's perspective, the routines facilitated deeper student explanations and supported instructional coherence, while also presenting challenges related to time management and instructional balance. Rather than advancing causal claims, the study offers context-sensitive insights into how systems thinking–oriented pedagogy can be enacted within everyday classroom practice. The findings highlight the pedagogical and leadership relevance of thinking routines as tools that support reflective, relational, and sustainability-oriented ways of thinking. By foregrounding the philosophical and normative dimensions of pedagogical design, the study contributes to ongoing discussions on how education can cultivate forms of thinking necessary for engaging responsibly with complexity in contemporary educational systems.

Keywords: Curriculum design; Educational leadership; Social studies education; Sustainability; Systems thinking; Teacher education; Thinking routines

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1. Introduction

Systems thinking, initially introduced by Forrester (1961) and later popularized by Senge (1990) in *The Fifth Discipline*, is a holistic approach to understanding complexity. Rather than focusing on isolated components, systems thinking emphasizes interconnections, feedback loops, and patterns of change within dynamic structures (Checkland, 2012; Senge, 1990). In recent years, this paradigm

Address of Corresponding Author

Erkan Bozkurt, PhD, Uşak University, Faculty of Education, Department of Social Sciences Education, 64000 Uşak, Türkiye.

erkan.bozkurt@usak.edu.tr

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has been recognized as a core twenty-first-century competency, essential for addressing complex and uncertain problems in education, sustainability, and organizational development (Arnold & Wade, 2015; York & Orgill, 2020).

Systems thinking has been conceptualized not only as a holistic way of understanding complexity but also as a framework for identifying system components, causal relationships, feedback loops, and patterns of change over time (Meadows, 2008; Richmond, 1994; Sterman, 2010). Empirical and conceptual studies emphasize that systems thinking involves recognizing interdependencies, anticipating system behavior, and reflecting on mental models that shape decision-making (Ben-Zvi Assaraf & Orion, 2010; Sweeney & Sterman, 2000).

In the context of education, systems thinking equips learners to view social and environmental phenomena as interconnected systems rather than as linear sequences of cause and effect. It supports inquiry-based and problem-based learning by engaging students in analyzing relationships, exploring consequences, and recognizing multiple perspectives (Hmelo-Silver, 2004; Mehren et al., 2018). Such skills are foundational not only for scientific literacy but also for civic and educational literacy, enabling learners to interpret the complexity of real-world challenges—from social inequality to ecological resilience. Despite this potential, systems thinking has rarely been introduced systematically at the primary and middle school levels, particularly outside the domain of science education (Feriver Gezer, 2018; Karaarslan Semiz & Teksoz, 2023; Oyman Bozkurt & Bozkurt, 2024).

Within the context of education for sustainable development [ESD], systems thinking has been identified as a core competency necessary for addressing complex global challenges (UNESCO, 2016, 2017). Research highlights that sustainability-related problems require learners to understand interactions between social, environmental, and economic systems and to consider long-term consequences rather than isolated events (Kamalam, 2017; Sterling, 2010). Accordingly, systems thinking is increasingly positioned as a foundational capacity in curriculum frameworks aimed at sustainability and global citizenship.

For educational administration, systems thinking offers a metacognitive lens for understanding and managing the inherent complexity of educational systems. It encourages decision-makers to view schools as adaptive, interdependent entities in which learning, leadership, and environment continuously interact (Prabawani et al., 2022). Integrating systems thinking early in schooling can therefore be viewed as a strategic foundation for sustainable educational governance—supporting the development of reflective, collaborative, and future-oriented learners who will later contribute to coherent and resilient education systems. This alignment between pedagogical design and systemic sustainability underscores the responsibility of educational leaders and policymakers to ensure that curricula cultivate such ways of thinking (UNESCO, 2016). In practical terms, this responsibility involves moving beyond fragmented curriculum objectives toward learning designs that explicitly foreground interconnections, feedback processes, and long-term consequences. Educational leaders play a key role in creating the organizational and instructional conditions that enable such pedagogical coherence, including curriculum alignment, teacher professional learning, and reflective school cultures. From this perspective, systems thinking is not only a student competency but also a guiding principle for curriculum leadership and sustainable educational governance.

From a leadership perspective, this systemic view aligns with contemporary approaches such as instructional leadership and distributed leadership, which emphasize coherence between curriculum design, teaching practices, and organizational learning. When pedagogical tools are deliberately selected to cultivate systems thinking, curriculum design itself becomes a leadership act that shapes how schools function as learning organizations. In this sense, integrating systems thinking into everyday classroom practices supports not only student learning but also the development of reflective, participatory, and sustainable school cultures.

Thinking routines, as proposed by *Project Zero* (Ritchhart et al., 2011), provide one practical framework for embedding systems thinking within everyday learning. By making thinking visible through structured prompts—such as observing details, tracing relationships, and considering multiple viewpoints—these routines foster reflection and cognitive engagement (Manurung et al., 2022; Tishman & Palmer, 2005). When aligned with systems thinking goals, thinking routines can help students externalize their mental models, identify interdependencies, and construct holistic understandings of complex issues (Kordova et al., 2018).

In addition to its pedagogical and organizational implications, systems thinking can also be approached as an epistemic orientation toward knowledge and learning. Rather than treating knowledge as fragmented and transmissible, systems thinking emphasizes relational understanding, reflexivity, and awareness of consequences over time. From an educational philosophy perspective, this orientation resonates with approaches that conceptualize education as the cultivation of judgment, agency, and meaning-making. Learning environments that make thinking processes visible therefore support not only cognitive development but also reflective engagement with how knowledge is constructed and used. Recent classroom-based research further suggests that pedagogical designs intentionally structured to foster creative and critical thinking can deepen students' engagement with complex learning tasks and reshape their epistemic participation in meaningful ways (Adewumi et al., 2025; Kwambaza & Basela, 2024; Nasution et al., 2025; Ponce de Leon, 2025).

Recent reviews and empirical studies indexed in major databases such as Scopus and Web of Science indicate that, despite growing interest in systems thinking in education, classroom-based research at the primary and middle school levels remains limited, particularly in non-STEM disciplines such as social studies (Karaarslan Semiz & Teksoz, 2023; Oyman Bozkurt & Bozkurt, 2024; York et al., 2019). Moreover, studies examining pedagogical scaffolds that explicitly support the development of systems thinking processes among younger learners are still scarce. This study addresses that gap by examining the implementation of systems thinking–oriented thinking routines in middle school social studies. The research further explores how such early experiences contribute to the development of the cognitive and reflective foundations necessary for sustainable educational systems and informed educational administration practices.

The significance of this study lies in its integrative focus on pedagogy, systems thinking, and educational leadership within a primary-level social studies context. By examining the use of visible thinking routines to support students' systems thinking development, the study provides empirical insight into an area that has received limited attention outside STEM education. Moreover, by framing pedagogical design as a leadership concern connected to sustainability and reflective school cultures, the study offers context-sensitive implications for curriculum planning, teacher practice, and educational leadership. As an exploratory case-based investigation, the findings provide a foundation for future research and practice aimed at embedding systems thinking into everyday schooling in coherent and sustainable ways.

2. Current Study

Today's education systems face the challenge of preparing learners to navigate increasingly complex and interconnected social, environmental, and technological realities. Developing systems thinking skills in early schooling has been recognized as an essential step toward building sustainable, adaptive educational systems (Arnold & Wade, 2015; Prabawani et al., 2022). However, despite growing theoretical attention, the practical integration of systems thinking into classroom pedagogy—especially in non-science subjects such as social studies—remains limited and underexplored (Karaarslan Semiz & Teksoz, 2023; York et al., 2019).

Thinking routines, developed by Harvard University's Project Zero group, offer a promising pedagogical tool for fostering such skills (Project Zero, 2023; Ritchhart et al., 2011). These structured prompts help students externalize and visualize their thought processes, enabling them to explore relationships, interactions, and feedback within complex systems. When thoughtfully integrated into the curriculum, they may help students develop systemic awareness, which, in turn, supports sustainable reasoning and decision-making—key competencies for lifelong learning and the coherent management of educational systems (Talley & Hull, 2023; UNESCO, 2017).

In the Turkish educational context, fostering these abilities aligns with both curriculum innovation and educational administration priorities. The Ministry of National Education [MoNE] has emphasized the importance of critical, creative, and holistic thinking yet there remains a gap between policy intentions and classroom practices. Bridging this gap requires empirical studies that investigate how visible thinking frameworks can cultivate systems thinking at an early age and how these practices can inform sustainable curriculum design (Chaaban et al., 2024).

Accordingly, this study aims to examine the effectiveness of visible thinking routines in developing systems thinking skills among fifth-grade students in social studies courses. Specifically, it seeks to answer the following research questions:

RQ 1) How does the use of visible thinking routines in social studies support students' systems thinking skills?

RQ 2) How do classroom processes unfold when thinking routines are integrated into learning activities?

RQ 3) What are students' perceptions of their experiences in developing systems thinking through thinking routines?

RQ 4) How do teachers perceive the influence of thinking routines on students' systems thinking development?

3. Method

3.1. Research Design

This study employed an exploratory, case-based mixed-methods design to investigate how visible thinking routines support the development of systems thinking in an authentic classroom context. A single-group pretest–posttest structure was used to document changes in students' systems thinking–related performances over time, complemented by qualitative data capturing classroom processes and participant experiences. The use of a mixed-methods approach was intended to enable a more comprehensive understanding of the phenomenon by integrating quantitative indicators of change with qualitative insights into learning processes and contextual dynamics, consistent with mixed-methods research traditions that emphasize complementarity and triangulation (Clark & Creswell, 2008). Given the absence of a control group and the limited sample size, the study does not aim to establish causal effects or generalizable outcomes. Instead, it seeks to generate context-sensitive and practice-oriented insights into pedagogical processes associated with the use of thinking routines in early schooling.

3.2. Participants

The study was conducted in a public middle school located in the western part of Türkiye. The participant group consisted of 26 fifth-grade students enrolled in a social studies course and their classroom teacher. Participants were selected through convenience sampling based on accessibility and willingness to participate.

3.3. Intervention

The implementation took place over an eight-week period during regular social studies lessons. The overall course flow and sequencing of the thinking routine activities implemented during this period are summarized in Table 1. Prior to the intervention, students were introduced to the basic principles of systems thinking and the purpose of visible thinking routines, while the teacher received a brief orientation regarding the alignment of routines with instructional objectives.

During the implementation phase, systems thinking–oriented thinking routines—such as *Behavior Over Time Graphs*, *Causal Loop Diagrams*, *Stock–Flow Diagrams*, and the *Ladder of Inference*—were systematically integrated into classroom activities addressing social and environmental topics. These routines were used to encourage students to observe patterns, identify relationships, and reflect on feedback processes within complex systems. Examples of the thinking routines and systems thinking tools used during the instructional intervention are provided in Appendix A.

Table 1
Overview of the instructional sequence and thinking routines

Week	*Topic*	*Implementation*
Week 1	Story of a Product	Pre-test – *Behavior Over Time Graph*, *Stock-Flow Diagram*
Week 2	Environmental Problems	Pre-test – *Causal Loop Diagram*, *Ladder of Inference*
Week 3	Conscious Consumer	*Parts, Purposes, Complexities* Thinking Routine
Week 4	Those Working for Society	*Parts, People, Interactions* Thinking Routine
Week 5	Administrative Units	*Parts, Perspectives, Me* Thinking Routine
Week 6	Province We Live in	*Imagine, If…* Thinking Routine
Week 7	Factors Affecting Population Difference of Technology	Post-test – *Behavior Over Time Graph*, *Stock-Flow Diagram*
Week 8	Impact of Natural Disasters	Post-test – *Causal Loop Diagram*, *Ladder of Inference*

3.4. Data Collection

Quantitative and qualitative data were collected to capture both changes in students' systems thinking–related performances and the processes through which classroom implementation unfolded. Quantitative data were collected through students' performances on systems thinking tools at both pre- and post-intervention stages. Qualitative data were gathered through (a) classroom observations focusing on instructional practices and student engagement, (b) student written reflections documenting learning experiences, and (c) a semi-structured interview with the classroom teacher conducted at the end of the implementation.

3.5. Data Analysis

Quantitative data were analyzed using descriptive statistics to examine patterns and tendencies in students' systems thinking–related performances across the pre- and post-intervention phases. Given the exploratory nature of the study and the small sample size, the analysis focused on observable shifts and developmental tendencies rather than hypothesis testing.

Qualitative data consisted of students' written reflections and a semi-structured teacher interview. The analysis was situated within an interpretivist epistemological stance, which assumes that meaning is constructed through participants' experiences and is co-interpreted through the researcher's analytic engagement. Accordingly, qualitative data were analyzed using reflexive thematic analysis (Braun & Clarke, 2019), which conceptualizes coding as an interpretive, theory-informed, and reflexive process rather than a purely mechanical categorization procedure.

The analytic process was iterative and recursive. First, the dataset was read multiple times to achieve deep familiarization. Initial descriptive codes were generated inductively from the data. Through constant comparison and reflexive memo writing, codes were refined and clustered into higher-order themes. While early coding remained data-driven, the development of themes was informed by the study's conceptual focus on systems thinking, pedagogical design, and leadership-relevant instructional practices.

In line with reflexive thematic analysis, themes were conceptualized as patterns of shared meaning underpinned by central organizing concepts (Braun & Clarke, 2019). The analysis prioritized interpretive coherence, depth, and explanatory insight rather than numerical representation. No frequency counts were calculated for codes or themes, as the aim was to identify qualitative shifts in reasoning, engagement, and classroom processes rather than to quantify responses.

Analytic rigor was enhanced through repeated engagement with the data, reflexive documentation of analytic decisions, and iterative refinement of thematic boundaries. The resulting thematic framework functioned as an analytic scaffold supporting the interpretive claims presented in the Findings and Discussion sections. Representative excerpts were selectively incorporated to illustrate themes while maintaining analytic clarity and narrative flow. The final thematic structure is presented in Table 2.

Table 2
Thematic Framework

Data Source and Theme	*Subtheme*	*Illustrative Focus*
Students		
Cognitive engagement and sense-making	Relational thinking	Identifying connections among system elements
	Reflective awareness	Questioning assumptions and reasoning processes
Affective responses and classroom experience	Enjoyment and interest	Positive emotional engagement with learning tasks
	Adaptation over time	Increasing comfort with open-ended inquiry
Teacher		
Observed student learning processes	Depth of explanation	Movement beyond surface-level responses
	Externalization of thinking	Use of visual tools to articulate reasoning
Instructional affordances and challenges	Pedagogical flexibility	Adapting routines to lesson contexts
	Instructional balance	Managing guidance and student autonomy

3.6 Ethics, Validity, and Reliability

Ethical considerations and strategies to enhance trustworthiness were integral to the design and implementation of this study. Given that the participants were fifth-grade students under the age of 18, informed consent was obtained from their parents or legal guardians prior to data collection. The research protocol was reviewed and approved by the Social Sciences and Humanities Scientific Research and Publication Ethics Committee of Uşak University (Decision No: 2023-114).

To support validity and reliability within the exploratory framework of the study, multiple strategies were employed. Data triangulation was achieved by drawing on diverse data sources, including students' performances on systems thinking tools, classroom observations, student written reflections, and a semi-structured interview with the classroom teacher. In addition, prolonged engagement in the classroom context over the eight-week implementation period allowed for sustained observation of instructional processes and student engagement, contributing to the credibility of the findings.

Given the qualitative components of the study, analytic rigor was supported through an iterative coding process and the systematic development of themes grounded in the data. Transparency in data analysis procedures and the use of visual and written artifacts further supported interpretive consistency. Consistent with the exploratory and context-sensitive aims of the study, issues related to methodological constraints and limitations are addressed in the Discussion and Conclusion section.

4. Results

4.1. Changes in Students' Systems Thinking–Related Performances

This section presents descriptive findings related to changes observed in students' systems thinking–related performances across the pre- and post-intervention phases. Given the exploratory nature of the study and the absence of a control group, the results are reported in terms of observable tendencies rather than causal effects.

Overall, students demonstrated higher levels of performance on systems thinking–related tasks following the implementation of visible thinking routines. Descriptive comparisons between pre-intervention and post-intervention measures indicated increases across several dimensions of systems thinking, including identifying system components, recognizing relationships among elements, and representing dynamic changes using visual tools.

In particular, post-intervention performances showed more consistent and complete representations in tasks involving *Behavior over Time Graphs* and *Causal Loop Diagrams*. Students were more likely to include multiple variables, depict directional relationships, and reflect temporal patterns in system behavior. Similarly, performances related to the use of the *Ladder of Inference* suggested greater awareness of reasoning steps and assumptions during post-intervention tasks.

It should be noted that in some measures, variability was limited, with identical scores observed across participants in the post-intervention phase. This lack of variation may indicate a ceiling effect, suggesting that the measurement tools may have been insufficiently sensitive to capture finer-grained differences in students' emerging systems thinking performances. Accordingly, the observed changes should be interpreted as indicative of general performance tendencies rather than precise estimations of individual growth.

Taken together, the descriptive findings suggest that the integration of visible thinking routines was associated with observable shifts in students' systems thinking–related task performances within this specific classroom context. These results provide an initial empirical basis for further exploration using more sensitive measurement instruments and comparative research designs. Descriptive statistics summarizing students' performances on systems thinking tools across the pre- and post-intervention phases are presented in Table 3.

Table 3
Descriptive Summary of Students' Performances on Systems Thinking Tools across Pre- and Post-Intervention Phases

Topic	*Tool*	*Phase*	*Mean*	*SD*	*N*
Story of a Product	Behavior Over Time Graph	Pretest	6.85	1.190	26
		Posttest	8.42	0.703	26
Difference of Technology	Stock–Flow Diagram	Pretest	7.85	1.405	26
		Posttest	10.65	1.056	26
Environmental Problems	Causal Loop Diagram	Pretest	6.00	1.233	26
		Posttest	8.12	0.766	26
Impact of Natural Disasters	Ladder of Inference	Pretest	3.04	0.824	26
		Posttest	4.00	0.000	26

*Note.*Identical post-test scores indicate a possible ceiling effect.

4.2. Classroom Processes during the Implementation of Thinking Routines

This section presents findings related to classroom processes observed during the implementation of visible thinking routines. The focus is on how instructional activities unfolded over time and how students engaged with systems thinking–oriented tasks within the social studies classroom.

Classroom observations indicated that the integration of thinking routines introduced a noticeable shift in the structure and pacing of lessons. Rather than progressing through content in a linear manner, lessons increasingly revolved around discussion, representation, and reflection. For example, during the "Conscious Consumer" unit, students worked in groups using the *Parts–Purposes–Complexities* thinking routine to collaboratively unpack the structure of consumption-related systems and articulate relationships among system elements (see Figure 1).

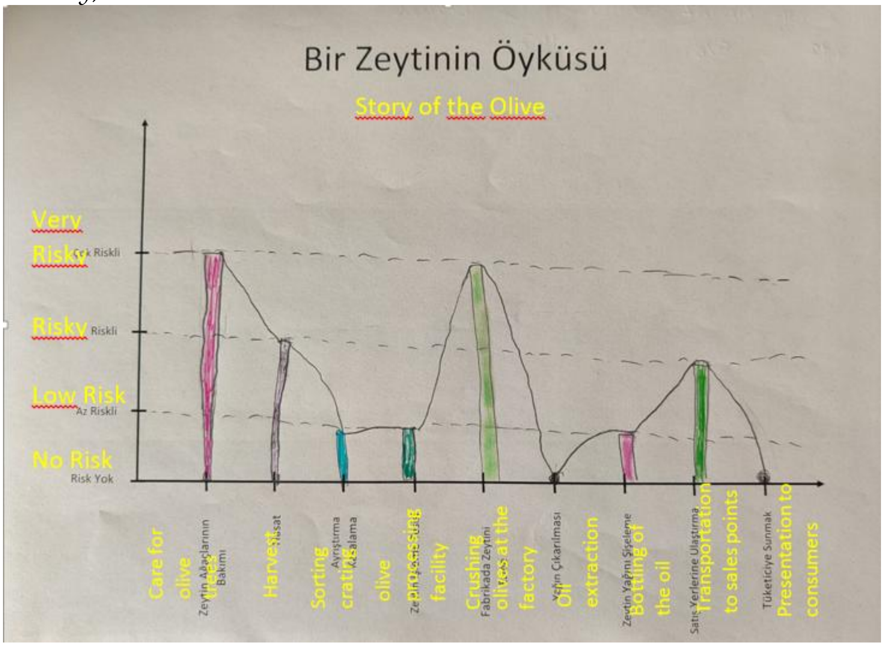
Figure 1
Example of student group work using the Parts–Purposes–Complexities thinking routine ("Conscious Consumer" activity)

In subsequent lessons, systems thinking tools were introduced to further support students' reasoning about dynamic relationships. During activities involving *Behavior Over Time Graphs*, students were encouraged not only to identify variables but also to discuss how these variables changed over time and how such changes might influence other elements within the system. This iterative structure encouraged sustained engagement with learning tasks rather than rapid completion of activities. An example of a student-generated pre-test *Behavior Over Time Graph* illustrating this initial, event-focused reasoning is presented in Figure 2. This artifact exemplifies a student-generated graph showing the changes over time of a selected social or environmental variable. The chosen topic here is the journey of olive oil from tree to consumer, and students were asked to graph the situations they perceived as risky at each stage as they listened to the story of the olive. The graph reflects the student's developing awareness of temporal dynamics, demonstrating their attempt to represent trends and turning points rather than isolated events.

During the early stages of implementation, some students required guidance to adapt to the open-ended nature of the routines. Initial responses often focused on listing isolated elements or providing brief explanations. Over time, however, students increasingly incorporated multiple variables into their representations and demonstrated greater willingness to revise their ideas. Classroom interactions became more dialogic, as students asked clarifying questions, responded to peers' contributions, and negotiated different interpretations of system behavior during whole-class discussions.

Observation data also suggested that visual representations played a central role in supporting classroom processes. Tools such as *Behavior Over Time Graphs* and *Causal Loop Diagrams* functioned as shared reference points, enabling students to externalize their thinking and engage in collective sense-making. In several lessons, differing diagrams produced by students or groups became focal points for discussion, prompting students to explain their reasoning and compare alternative representations. These visual artifacts made students' thinking visible and accessible to others,

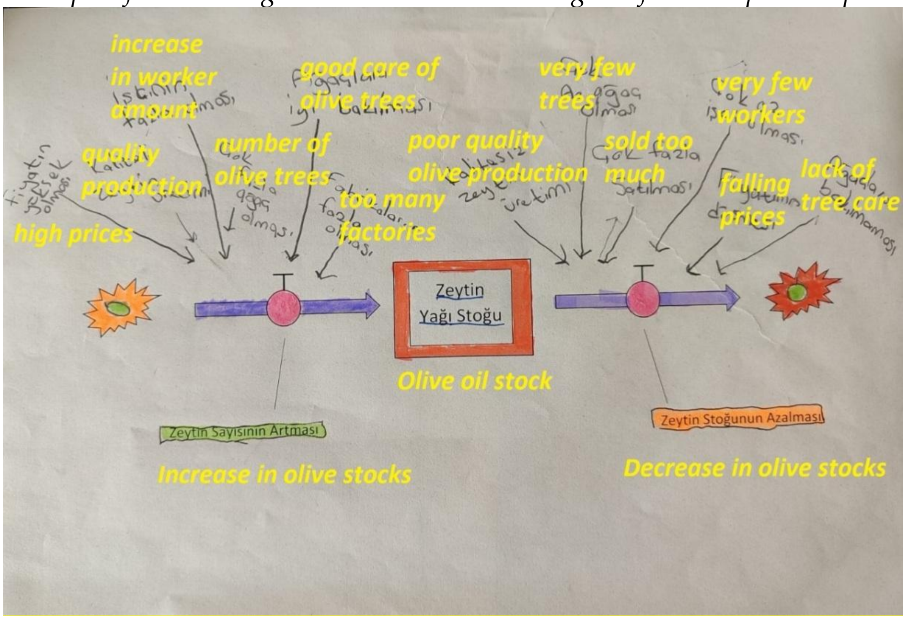
Figure 2
Example of a student-generated Behavior over Time Graph from the pre-test phase ("Story of the Olive" activity)



thereby supporting collaborative exploration of complex issues. For instance, students' pre-test *Stock–Flow Diagrams* often emphasized surface-level factors influencing system inputs and outputs, with limited attention to feedback mechanisms, as illustrated in Figure 3. This example shows a student-created visual representation of relationships among multiple factors within a system. The artifact highlights how students used arrows and brief annotations to express perceived causal connections and interdependencies.

Students worked on this diagram to more clearly visualize the factors that increase and decrease olive oil stock and the relationship between them. The aim here is to be able to see all factors as a whole and to more clearly explore causal connections. All students' artifacts were anonymized prior to inclusion. The examples were selected to represent typical classroom outputs rather than exemplary or exceptional work.

Figure 3
Example of a student-generated Stock–Flow Diagram from the pre-test phase (olive oil production system)



Throughout the implementation, the teacher adopted a facilitative role, prompting students to explain their reasoning, justify connections, and reflect on alternative perspectives. Rather than evaluating responses as correct or incorrect, instructional interactions emphasized explanation and revision. Instructional interactions emphasized explanation and revision, which appeared to support a classroom climate in which students felt comfortable expressing tentative ideas and engaging in reflective dialogue.

Overall, the findings indicate that integrating visible thinking routines shaped classroom processes by promoting iterative learning, dialogic interaction, and the use of visual representations as tools for collective inquiry. These process-oriented findings provide insight into how systems thinking–oriented pedagogical practices can be enacted within everyday classroom contexts and offer contextual grounding for the student perspectives reported in the following section.

4.3. Students' Views on Thinking Routine Experiences

Students' perspectives on the use of thinking routines were examined through written reflections collected at the end of the implementation period. The analysis revealed two overarching themes related to students' experiences: (a) cognitive engagement and sense-making and (b) affective responses and classroom experience.

4.3.1. Cognitive engagement and sense-making

Many students described the thinking routines as tools that supported deeper understanding by helping them organize their ideas and recognize relationships among concepts. Rather than focusing solely on isolated facts, students reported that they were encouraged to consider how different elements interacted within a system and how changes in one part could influence others. One student reflected this shift by stating, "I could see how everything was connected, not just one part" (Student 7).

Students' reflections also indicated increased awareness of their own thinking processes. Some students reported that the routines prompted them to question their initial assumptions and reconsider their ideas when presented with alternative explanations. This reflective dimension was particularly evident in tasks that required students to justify causal relationships or explain changes over time. As one student noted, "I started thinking about why things happen, not just what happens" (Student 12). Overall, students perceived the routines as supporting sense-making by making complex ideas more manageable and structured.

4.3.2. Affective responses and classroom experience

In addition to cognitive engagement, students frequently commented on their emotional and experiential responses to the thinking routines. Many students described the activities as enjoyable and engaging, emphasizing that working with visual representations and discussing ideas with peers made lessons feel more interactive. Expressions such as "having fun" were commonly associated with opportunities to draw, discuss, and collaborate rather than with task difficulty or performance outcomes. One student succinctly expressed this experience: "It was fun because we could talk and draw our ideas" (Student 4).

Some students also acknowledged initial challenges, particularly at the beginning of the implementation, when they were unsure how to approach open-ended tasks. However, these challenges were often framed positively, with students noting that they became more comfortable over time as they gained experience with the routines. As one student explained, "At first it was confusing, but later it became easier" (Student 19). Overall, students' affective responses suggest that the thinking routines contributed to a classroom experience characterized by increased participation, interest, and willingness to engage with complex ideas.

4.4. Teacher Views on the Use of Thinking Routines

Teacher perspectives were examined through a semi-structured interview conducted at the end of the implementation period. The analysis yielded two overarching themes: (a) observed student learning processes and (b) instructional affordances and challenges associated with the use of thinking routines.

4.4.1. Observed student learning processes

From the teacher's perspective, integrating thinking routines influenced how students approached learning tasks and articulated their ideas. The teacher reported that students increasingly moved beyond brief or surface-level responses and began to explain relationships among concepts more explicitly. This shift was summarized by the teacher as follows: "Students started explaining their ideas instead of giving short answers."

The teacher also noted that visual tools supported students in expressing complex ideas that might otherwise have remained implicit. By externalizing their thinking through diagrams and graphs, students were able to communicate their reasoning more clearly during whole-class discussions. As the teacher observed, "The diagrams helped students show what they were thinking."

4.4.2. Instructional affordances and challenges

In terms of instructional affordances, the teacher emphasized that thinking routines provided a flexible structure that could be adapted to different lesson topics within the social studies curriculum. The routines were described as supporting student participation and facilitating classroom dialogue without requiring extensive changes to existing lesson plans.

At the same time, the teacher identified several challenges associated with implementation. These included managing classroom time, supporting students who initially struggled with open-ended tasks, and balancing guidance with opportunities for independent thinking. Reflecting on this balance, the teacher noted, "Sometimes it was difficult to decide how much guidance to give." The teacher also indicated that familiarity with the routines increased over time, reducing some of these challenges as students became more accustomed to reflective and dialogic learning practices. Overall, the teacher's views highlight both the potential and the practical considerations involved in integrating systems thinking–oriented routines into everyday classroom instruction.

5. Discussion and Conclusion

5.1. Interpreting the Findings within an Exploratory Framework

The findings of this study should be interpreted within the boundaries of its exploratory design and contextual scope. The study did not aim to establish causal effects or to test the effectiveness of thinking routines through experimental comparison. Rather, it sought to explore how systems thinking–oriented pedagogical practices unfold within an authentic classroom context and how students and teachers experience these practices over time. This positioning aligns with research traditions that conceptualize classroom-based interventions as situated and exploratory inquiries rather than controlled experiments (Cobb et al., 2003; Maxwell, 2012). Recent classroom-based research on visible thinking and systems-oriented pedagogy also emphasizes the importance of examining learning as a context-sensitive and process-oriented phenomenon, particularly in studies that prioritize pedagogical enactment over causal attribution (Chen & Jan, 2024; Peng et al., 2023).

The observed increases in mean scores across systems thinking tools suggest shifts in how students approached complex tasks and articulated relationships among concepts. However, these patterns must be understood as context-specific outcomes shaped by multiple interacting factors, including classroom dynamics, teacher facilitation, task familiarity, and students' developing reflective capacities. Empirical studies adopting larger samples and quasi-experimental designs have likewise cautioned against linear interpretations of learning outcomes in pedagogies that foreground higher-order thinking, showing that observed gains often emerge through mediating processes such as scaffolding, reflective engagement, and pedagogical design rather than direct instructional effects (Ramos-Vallecillo et al., 2024; Yeh et al., 2025). Similar cautions regarding interpretation have been emphasized in systems-oriented educational research, which foregrounds emergence, interaction, and contextual sensitivity over linear input–output models of learning (Checkland, 2012; York & Orgill, 2020).

Framing the study as exploratory therefore strengthens its contribution by foregrounding learning processes rather than instructional effects. Such an approach is consistent with systems thinking perspectives that view educational change as iterative, relational, and contingent, rather than predictable or uniform across contexts (Arnold & Wade, 2015; Senge, 1990). It also resonates with research traditions that seek to generate contextually grounded insights into pedagogical practice, emphasizing how learning unfolds within specific instructional ecologies rather than producing generalized claims of effectiveness (Chen & Jan, 2024). From this perspective, the present findings contribute not by demonstrating effectiveness in a narrow sense, but by illuminating how systems thinking–oriented pedagogical practices are enacted and experienced within a particular classroom context.

5.2. Pedagogical Design, Systems Thinking, and the Aims of Education

The findings highlight the role of pedagogical design in shaping students' engagement with systems thinking. The integration of thinking routines into social studies lessons functioned not merely as an instructional technique but as a structured way of organizing inquiry, reflection, and dialogue. Similar studies have shown that making thinking visible through structured routines can support learners in articulating relationships and developing more coherent mental models of complex phenomena (Hmelo-Silver, 2004; Ritchhart et al., 2011). More recent classroom-based research further suggests that when thinking routines are embedded as recurring elements of instructional design, they support sustained engagement with complex ideas by providing learners with stable cognitive and dialogic structures rather than isolated activities (Chen & Jan, 2024; Panzavolta et al., 2019).

From a broader educational perspective, this alignment between pedagogical design and systems thinking reflects underlying assumptions about the nature and purpose of learning. Rather than treating knowledge as a set of discrete facts to be transmitted, the routines positioned learning as an active, reflective, and relational process. Empirical studies of visible thinking–oriented pedagogy indicate that such designs can foster epistemic agency by encouraging learners to externalize, revisit, and refine their reasoning over time, thereby supporting learning as an ongoing process of sense-making rather than outcome production (Peng et al., 2023; Yeh et al., 2025). This orientation resonates with philosophical perspectives that conceptualize learning as inquiry and experience rather than transmission, emphasizing reflection, meaning-making, and relational understanding (Biesta, 2015; Dewey, 1938).

The connection between systems thinking and sustainability further reinforces this philosophical dimension. Preparing students to engage with interconnected social and environmental issues requires pedagogical approaches that cultivate holistic reasoning, perspective-taking, and awareness of long-term consequences. Research in education for sustainability similarly emphasizes that such capacities are fostered not only through curricular content but through pedagogical practices that support reflective and systems-oriented ways of thinking (Sterling, 2010; UNESCO, 2017). Studies examining systems-oriented and project-based pedagogies suggest that these capacities are most effectively developed when instructional designs make relationships, processes, and consequences explicit and open to collective examination (Ramos-Vallecillo et al., 2024).

Taken together, the findings suggest that pedagogical tools such as thinking routines are not value-neutral. They implicitly communicate educational aims related to reflection, relational understanding, and ethical awareness. Large-scale classroom studies of visible thinking approaches similarly demonstrate that such tools shape classroom norms around inquiry, participation, and responsibility, particularly by supporting learners who may otherwise struggle to engage with complex and open-ended tasks (Peng et al., 2023). By embedding systems thinking within everyday classroom practices, educators enact a vision of education oriented toward responsible participation in complex systems—an orientation that carries both pedagogical and philosophical significance.

5.3. Thinking Routines as Leadership-Relevant Pedagogical Practices

Although this study was conducted at the classroom level, the findings have clear implications for educational leadership when pedagogy is viewed as a collective and value-laden practice rather than an individual instructional choice. The integration of thinking routines to support systems thinking reflects leadership-relevant decisions about curriculum priorities, instructional coherence, and the kinds of cognitive dispositions schools aim to cultivate. Research on pedagogical design similarly suggests that instructional choices embedded in everyday classroom practice often function as implicit leadership acts, shaping shared understandings of learning, participation, and responsibility (Chen & Jan, 2024). In this sense, pedagogy becomes a key site where leadership is enacted through everyday instructional practices.

From a distributed leadership perspective, the use of thinking routines illustrates how leadership functions can be embedded within classroom practices rather than residing solely in formal administrative roles. Distributed leadership emphasizes shared responsibility for instructional improvement and the alignment of teaching practices with broader educational goals (Spillane, 2006). By adopting routines that make thinking visible and support relational reasoning, teachers participate in leadership work that contributes to a coherent learning culture oriented toward systems thinking. Studies of collaborative and reflective practice indicate that such routines can also function as shared sense-making tools, supporting collective reflection and professional dialogue among educators as well as students (Prout et al., 2021). Such practices exemplify how leadership can be exercised through pedagogical design choices that shape collective norms around inquiry, dialogue, and reflection.

The findings also resonate with principles of instructional leadership, which foreground the central role of teaching and learning in school improvement efforts (Hallinger, 2011). From this perspective, leadership involves creating conditions that support pedagogical approaches aligned with long-term educational aims. The reported shifts in students' engagement and reasoning suggest that thinking routines can serve as instructional tools that align classroom practice with broader goals related to sustainability, complexity, and reflective thinking. Empirical research on visible thinking–oriented pedagogy further indicates that such alignment is most effective when teachers are supported in making coherent design decisions that connect curricular intentions, classroom activities, and assessment practices (Peng et al., 2023). Leaders who prioritize such alignment play a crucial role in ensuring that curricular intentions are translated into meaningful classroom experiences.

Beyond organizational considerations, systems thinking–oriented pedagogy carries a normative dimension that connects leadership to educational values and purposes. Systems leadership literature emphasizes the need for leaders to address complexity by fostering shared understanding, learning-oriented cultures, and adaptive capacity (Senge et al., 2015). In this light, supporting pedagogical practices that cultivate systems thinking reflects a leadership stance committed not only to effectiveness but also to ethical and epistemological considerations about how learners understand and engage with the world.

Taken together, these perspectives suggest that thinking routines function as leadership-relevant pedagogical practices that bridge classroom instruction and systemic educational goals. By embedding systems thinking into everyday teaching, educational leaders—whether school principals, middle leaders, or teacher leaders—contribute to the development of learning environments that value relational understanding, reflective inquiry, and responsible participation in complex systems. This integration positions leadership as a form of pedagogical stewardship, in which instructional design choices are understood as deliberate expressions of broader educational commitments rather than neutral technical decisions.

5.4. Student Engagement and Motivation: Affective Dimensions of Systems Thinking

The affective responses reported by students—particularly enjoyment, interest, and increased participation—can be meaningfully interpreted through established theories of student motivation and engagement. Rather than viewing these responses as incidental or secondary outcomes, motivation-oriented perspectives suggest that affective engagement plays a central role in sustaining cognitive effort and supporting deeper learning processes, especially in complex and open-ended tasks. Recent empirical studies of visible thinking and inquiry-oriented pedagogies similarly indicate that affective engagement often emerges as an integral component of learning processes that require sustained reasoning, reflection, and sense-making, rather than as a by-product of task novelty (Peng et al., 2023; Ramos-Vallecillo et al., 2024).

Self-Determination Theory [SDT] offers a useful framework for understanding how thinking routines may have supported students' engagement (Ryan & Deci, 2000). According to SDT, learning environments that support autonomy, competence, and relatedness are more likely to foster intrinsic motivation. In this study, the use of thinking routines provided students with opportunities to express their own ideas, make sense of relationships through visual representations, and engage in dialogue with peers. These features align with autonomy-supportive practices, as students were encouraged to explore multiple perspectives rather than arrive at predetermined answers. Studies examining structured yet open-ended pedagogical designs have likewise shown that opportunities for choice, interpretation, and dialogue contribute to students' sense of agency and ownership over learning tasks (Yeh et al., 2025).

At the same time, students' references to gaining confidence and becoming more comfortable with the routines over time suggest the development of perceived competence. The structured yet flexible nature of thinking routines may have supported this process by offering clear cognitive scaffolds while still allowing for individual interpretation and reasoning. Prior research has similarly indicated that well-designed scaffolds can enhance students' sense of competence in complex learning environments, thereby sustaining engagement and persistence (Hmelo-Silver et al., 2007). Large-scale classroom studies further suggest that such scaffolding effects may be particularly salient for students who initially struggle with open-ended tasks, supporting more equitable participation and sustained effort across learners (Peng et al., 2023).

The collaborative and dialogic aspects of the routines also speak to the role of relatedness in student motivation. Opportunities to discuss ideas, share visual representations, and build collective understanding can foster a sense of belonging and mutual recognition within the classroom. Engagement theories emphasize that such social dimensions of learning are particularly important for maintaining interest and participation, especially in inquiry-based and reflective pedagogies (Fredricks et al., 2004). Qualitative studies of thinking routines further highlight that collaborative reflection and shared sense-making can strengthen learners' emotional connection to both the task and the learning community, reinforcing motivation through social interaction rather than competition (Panzavolta et al., 2019).

Importantly, the affective dimension of systems thinking should not be interpreted as separate from its cognitive aims. Enjoyment and engagement, as reported by students, appear to have emerged from meaningful intellectual activity rather than from superficial task features. This suggests that systems thinking–oriented pedagogy can simultaneously support rigorous cognitive engagement and positive emotional experiences, reinforcing arguments that motivation and learning are deeply interconnected processes. Research on thinking routines and design-based pedagogies similarly underscores that affective engagement is most sustainable when it is grounded in epistemically rich tasks that invite learners to grapple with complexity, ambiguity, and multiple perspectives (Chen & Jan, 2024). Recognizing this interdependence has implications for both pedagogical design and leadership decisions, particularly in contexts where sustaining student engagement in complex learning is a persistent challenge.

6. Implications, Limitations, and Conclusion

The findings of this exploratory study offer several implications for pedagogy and educational leadership while also highlighting important limitations that shape the scope of interpretation. Rather than advancing generalizable claims about effectiveness, the study contributes context-sensitive insights into how systems thinking–oriented pedagogical practices can be meaningfully integrated into everyday classroom instruction, consistent with calls for sustainability-oriented pedagogy that emphasizes learning processes over standardized outcomes (Sterling, 2010; UNESCO, 2017). Recent empirical research on visible thinking and systems-oriented pedagogy similarly underscores the value of process-focused approaches that illuminate how learning unfolds within specific instructional contexts rather than reducing outcomes to decontextualized performance measures (Chen & Jan, 2024; Ramos-Vallecillo et al., 2024).

From a pedagogical perspective, the study suggests that thinking routines can serve as practical scaffolds for supporting students' engagement with complex and relational forms of reasoning. The combination of structured prompts, visual representations, and dialogic interaction appeared to support both cognitive and affective dimensions of learning. Large-scale classroom studies of thinking routines further indicate that such scaffolds can help sustain engagement across diverse learners by making complex thinking processes explicit and accessible, particularly in tasks that require interpretation, perspective-taking, and synthesis (Peng et al., 2023). These findings align with broader arguments that education for sustainability and complexity depends not only on curricular content but also on pedagogical forms that cultivate reflection, perspective-taking, and ethical awareness (Biesta, 2015).

The study also carries implications for educational leadership, particularly when leadership is understood as a practice that shapes instructional coherence and educational purpose. Supporting the integration of systems thinking into classroom practice requires leadership approaches that value pedagogical alignment, professional dialogue, and shared responsibility for learning (Hallinger, 2011; Spillane, 2006). Research on pedagogical design and instructional coherence suggests that such alignment is most likely to be sustained when leadership supports teachers in making deliberate and reflective design choices that connect curricular aims, classroom practices, and assessment (Chen & Jan, 2024). Importantly, such leadership work is not merely technical but normative, involving judgments about the kinds of thinking and dispositions schools seek to foster.

Several limitations must be acknowledged. The study was conducted with a small sample drawn from a single classroom, which limits the external validity of the findings. The absence of a control group and the use of instructional tools as both learning and assessment instruments introduce potential threats to internal and construct validity, including instrumentation bias and ceiling effects observed in some measures. Similar methodological constraints have been reported in both quasi-experimental and design-oriented classroom studies of thinking routines, reinforcing the importance of interpreting findings as indicative of learning processes rather than definitive evidence of instructional effectiveness (Peng et al., 2023; Yeh et al., 2025). These concerns are well documented in methodological literature on classroom-based and small-sample research and reinforce the need for cautious interpretation (Maxwell, 2012; Shadish et al., 2002).

Future research could build on this work by employing larger and more diverse samples, incorporating comparative or longitudinal designs, and using independent, validated instruments to assess systems thinking development. Design-based and mixed-methods approaches may be particularly valuable for examining how pedagogical design decisions and leadership practices interact over time to support the sustainability of systems thinking–oriented pedagogy across classrooms and schools (Chen & Jan, 2024). Further studies might also explore how leadership practices mediate the sustainability of systems thinking–oriented pedagogy across classrooms and schools, as well as examine the philosophical assumptions that underpin different approaches to systems-based education.

In conclusion, this study contributes to ongoing conversations about systems thinking, pedagogy, and educational leadership by illustrating how thinking routines can function as both instructional tools and expressions of educational values. By situating systems thinking within everyday classroom practice, the study underscores a vision of education oriented toward reflective, relational, and ethically grounded ways of thinking. Evidence from recent classroom-based research suggests that such practices can support not only students' cognitive development but also their sense of agency, responsibility, and engagement with complexity (Peng et al., 2023; Ramos-Vallecillo et al., 2024). Such a vision positions pedagogy and leadership as intertwined practices that shape not only what students learn, but how they come to understand and engage with the complexity of the world (Biesta, 2022).

Data availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of interest: The authors declared that there were no potential conflicts of interest.

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Appendix A. Thinking Routine Tasks and Systems Thinking Tools Used in the Study

This appendix provides an overview of the thinking routines and systems thinking tools implemented during the instructional intervention. The descriptions are intended to clarify how each tool was integrated into classroom activities without extending the Method section.

Behavior Over Time Graphs (BOTG)

Behavior Over Time Graphs were used to support students in analyzing patterns of change. In the context of social studies lessons, students constructed graphs to represent how specific social, technological, or environmental variables evolved across different time periods. This activity encouraged learners to move beyond static descriptions and consider trends, fluctuations, and long-term dynamics within systems.

Causal Loop Diagrams (CLD)

Causal Loop Diagrams were introduced to help students identify cause–effect relationships and feedback loops within complex social and environmental systems. Students worked collaboratively to map relationships among variables, using arrows to indicate directionality and influence. The focus was placed on recognizing interdependencies rather than producing technically perfect diagrams.

Stock–Flow Diagrams

Stock–Flow Diagrams were used to illustrate accumulation and change within systems. Students explored how resources, populations, or processes increased or decreased over time as a result of inflows and outflows. This tool supported discussions about balance, growth, and limits in real-world contexts.

Ladder of Inference

The Ladder of Inference was used as a reflective thinking routine to help students understand how observations lead to interpretations, assumptions, and conclusions. Through guided discussion and short written reflections, students examined how personal beliefs and prior knowledge shaped their reasoning about social issues and events.

Across all tools, thinking routines served as cognitive scaffolding to prompt observation, explanation, justification, and reflection. The emphasis was placed on sense-making and relational understanding rather than on correctness or formal assessment performance.