

Embodied Learning of Graphs: A Psychodramatic Approach in Primary School

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Abstract. While graph theory plays a foundational role in informatics and computational thinking (CT), its instruction in elementary education remains underexplored, particularly through embodied or arts-based methods. This study examines a low-tech, psychodrama-based pedagogical intervention designed to introduce graph theory as a data structure to fifth-grade students in a Brazilian public school. Students engaged in dramatizing connections and structural changes within friendship networks, enabling experiential learning of concepts such as adjacency, traversal, and modification of graph-like structures. Data were collected through teacher interviews, classroom observations, and post-intervention assessments. Findings indicate strong student engagement, symbolic appropriation of key graph concepts, and the development of abstraction and reflection skills central to computational thinking. These results suggest that educational psychodrama offers a culturally responsive, embodied strategy for introducing core CT concepts in early education, expanding the repertoire of practices in computing education.

Keywords: Graph, Data Structure, Computational Thinking, Educational Psychodrama, Embodied Cognition, Elementary Education.

1. Introduction

Graphs are structures that represent relationships between elements, and they appear in various everyday situations, including transportation networks (e.g., traffic maps, subway line maps), social networks, and tournament brackets. In the scientific field, researchers use graphs to model complex problems, such as those found in computational biology and network theory. Given their presence in daily life and across various areas of knowledge, introducing graphs' core concepts during the early years of elementary education is crucial.

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Additionally, discussing graphs supports the development of computational thinking, an essential skill in contemporary education (Wing and Stanzione, 2016). By exploring basic concepts such as the connection between elements (adjacency), possible paths between elements (graph traversal), and structural modifications (adding and removing elements), educators stimulate students' ability to abstract, recognize patterns, and decompose problems (Gibson, 2012). Moreover, understanding the specific features of data structures, such as graphs, is essential for selecting the most appropriate structure for a given problem, an analytical process closely tied to formulating efficient algorithms (Michaelson, 2015).

The literature on teaching graphs has provided several contributions in the context of mathematics (Blanco and García-Moya, 2021; Silva, 2015). Considering its intersection with computational thinking, noteworthy studies have approached graph-related concepts (e.g., coloring, shortest paths, traversal) through the use of tools such as games (Costa et al., 2017), microelectronic devices (Bonani et al., 2021), and problem-based learning (Lazarova et al., 2022). However, this body of work has not addressed the perspectives of embodied cognition, collaboration, and emotion, which are central to educational psychodrama. The basic graph concepts discussed earlier, however, hold great potential for exploration through psychodramatic perspectives. These concepts can be experienced in a physical and dramatized manner, promoting emotional and sensory engagement that enhances meaningful learning.

Considering this opportunity, this exploratory study describes and analyzes an educational psychodrama-based intervention designed to develop basic graph concepts. We implemented this intervention with two fifth-grade elementary school classes ($N = 41$), which were conducted by specially trained teachers. Data collection involved both qualitative and quantitative instruments, including field notes from the observer-researcher, interviews with the teachers, and a post-intervention assessment. Building on these methods, the study raises the following research question:

Can a pedagogical intervention based on psychodramatic pedagogy promote engagement, appropriation, and reflection among fifth-grade elementary school students regarding concepts such as the connection between elements, traversal, and modifications in graph-like structures?

This work is organized as follows: In Section 2, we outline related works. We discuss the school context and the pedagogical framework used to design our intervention in Section 3, while presenting our methodological components in Section 4. We present and discuss the intervention's outcomes in Sections 5 and 6, respectively. In Sections 7, we examine the threats to the validity of these results while concluding this work in Section 8.

2. Related Works

We reviewed the literature that investigates the teaching of graphs to different audiences, with particular emphasis on elementary education. We maintained a broad scope to identify studies that, although not explicitly referencing Computational Thinking (CT), may

align with its principles and competencies.

Several studies have proposed interventions based on hands-on activities (both manual and combined with digital tools) to explore graph theory in the context of Mathematics. For example, a 12-week course introduced third- and fourth-grade children (ages 9 to 10) to various graph topics, including Hamiltonian, Eulerian, and planar graphs, using a combination of games, online graph editors, and physical representations with paper, markers, and yarn (Ferrarello, 2017; Blanco and García-Moya, 2021). In a similar approach, Silva (2015) described an eight-lesson course for seventh-grade students, and Honda et al. (2022) reported the use of a serious game to explore graph traversal and shortest paths with high school students. Conversely, other works focus on a conceptual and logical introduction. For example, Laible (1970) presented a curricular and opinion piece advocating for the introduction of Graph Theory in Junior High and High School mathematics, relying on classic logical puzzles (e.g., Königsberg Bridges) to stimulate abstract reasoning. Similarly, Hamkins (2015) described how eight-year-old children can grasp the notions of nodes and edges through logical puzzles and visual representation (e.g., coloring the vertices of a cube), focusing solely on the conceptual introduction of the graph structure.

Moving more directly into the domain of CT, the majority of related work utilizes graph theory to enhance abstract and algorithmic thinking through logical problem-solving. These efforts include studies where students solve analytical puzzles related to Sudoku and scheduling problems (Costa et al., 2017; Lazarova et al., 2022), or develop algorithms for tasks such as the minimum spanning tree (Lehmann, 2024). For instance, Budinská and Mayerová (2019) converted Bebras Challenges into short, individual, paper-based worksheets to develop understanding of directed graphs and path structures, focusing exclusively on logical reasoning. The seminal Computer Science Unplugged (CS Unplugged) methodology further reinforces this trend by teaching core graph concepts (e.g., Graph Coloring, MST) through hands-on, unplugged activities (Bell et al., 1998). While highly practical, the CS Unplugged approach is fundamentally procedural, relying on algorithmic execution and the manipulation of external artifacts, thereby prioritizing cognitive, logical, and analytical skills over collaborative or explicit socio-affective exploration.

The literature also explores approaches based on technology and various modalities to boost engagement and understanding of graph theory. Studies have shown that utilizing interactive technologies (such as microelectronic objects) or playful sessions can lead to significantly higher engagement compared to traditional paper-and-pencil methods in high school and elementary settings (Bonani et al., 2021; Gibson, 2012). Furthermore, the concept of embodied learning has been explored through Virtual Reality (VR), with Chatain et al. (2023) showing that individual bodily interaction in VR enhances engagement with abstract graph concepts in undergraduates. Critically, this form of embodiment remains non-collaborative and focused on sensorimotor feedback. Conversely, studies anchored in standardized assessment, like that by Vaniček et al. (2021), employ the Bebras Challenge methodology (using logical puzzles and multiple-choice quizzes) primarily to test and foster cognitive processes and the abstraction of structural properties (e.g., isomorphism) in students from 11 years of age, entirely bypassing active or affective learning. Collectively,

these works (whether focused on algorithmic execution, technological interaction, individual sensorimotor embodiment, or purely cognitive testing) demonstrate a substantial gap in research utilizing collaborative, embodied dramatization and the explicit socio-affective dimension for conceptual learning of graph structures in primary school.

However, educational approaches that integrate emotional and embodied dimensions into the teaching of Computational Thinking (CT) and graphs remain rare, and we found no studies that applied educational psychodrama to this domain. Educational psychodrama employs dramatization, role-taking, and guided reflection as pedagogical strategies for teaching disciplinary content through action and collective meaning-making, rather than employing therapeutic techniques (Blatner, 1996). Previous research demonstrates that psychodrama can effectively support the teaching and learning of complex subjects. In higher education, it has been used to teach medical and nursing practices, helping students rehearse diagnostic reasoning, patient communication, and ethical decision-making (Liberali and Grosseman, 2015; Arveklev et al., 2015; Yee et al., 2024). It has also been adopted in teacher education to develop active and reflective teaching methodologies (Maya and Maraver, 2020), and in graduate programs to foster conceptual understanding through critical reflection and embodied experience (Nolte, 2025). Across these contexts, dramatization acts as a tool for exploring abstract or interpersonal dimensions of disciplinary knowledge while simultaneously strengthening collaboration as a learning support.

At the elementary level, psychodrama-based interventions have been used successfully to teach content in science, history, and social studies (Beck and Czerniak, 2005; Green and Cassani, 2020; Wilcox and Sterling, 2006; Cruz and Murthy, 2006; Fennessey, 2000). These studies consistently report gains in engagement, conceptual understanding, and cooperative problem-solving (Green and Cassani, 2020). Nevertheless, few approaches in CT or graph education have deeply explored embodied cognition or considered the emotional dimensions of learning. Therefore, our work addresses a critical gap in the literature: the absence of studies that introduce fundamental graph concepts to fifth-grade students using educational psychodrama as a means to explicitly foster embodied, affective, and relational learning.

This study contributes to the literature by extending the pedagogical use of educational psychodrama to the teaching of CT and graphs, proposing an intervention that integrates mind, body, and affective dimensions in the construction of basic computational and mathematical concepts.

3. Background

3.1 Participant School Profile

We conducted this study at a public school in São Paulo, Brazil, which serves more than 200 children in elementary education. The Social Assistance Reference Center refers these students, who come from low-income and vulnerable communities, to this school. Regard-

ing the fifth-grade classes, which are the focus of this study, school records indicate that approximately 60% of the children have studied together since second grade. The remaining members joined the group starting in the third grade. This information is relevant for understanding the level of familiarity among the class members.

The school adopts the São Paulo Curriculum (SEDUC-SP, 2019), an educational framework inspired by international references such as the Common Core Standards (United States) and the National Curriculum (United Kingdom). This curriculum prioritizes the development of core competencies, problem-solving, interdisciplinary learning, and active learning, aiming to prepare students for contemporary global challenges while also considering local contexts. The São Paulo Curriculum also integrates elements of Computational Thinking across various subject areas, with particular emphasis on Mathematics and Technology & Innovation. However, despite this innovative orientation, the school faces structural limitations, such as limited access to computers and the Internet, as well as a lack of teacher training in Computational Thinking. These limitations hinder the effective implementation of CT-related activities.

In the fifth grade of elementary school (typically ages 10 to 11), the curriculum emphasizes the development of CT in Mathematics, particularly through the understanding of algorithms involving simple repetition. Although the formal concept of a “graph” is not included at this level, it can be indirectly addressed within the geometry unit. In this unit, students engage in activities that involve interpreting, describing, and representing the position and movement of objects on the Cartesian plane. This concrete approach provides an intuitive foundation for introducing fundamental graph concepts, as proposed in this study.

Given the students’ age group and their lack of prior exposure to graph theory, this study intentionally addressed only the fundamental components of the topic (nodes, edges, adjacency, simple traversal), which represent the conceptual core upon which more advanced graph operations (e.g., directed graphs, search algorithms) could later be introduced. This introductory scope was essential to ensure accessibility and conceptual clarity in the early stages of graph learning. Future studies could extend this work by integrating psychodramatic or plugged approaches to explore more complex graph concepts once students have internalized these foundational ideas.

3.2 Motivation and Pedagogical Framework

This study is grounded in educational psychodrama, an active approach that recognizes psychodrama as a tool for fostering a participatory and collaborative learning environment (Romaña, 2010; Moreno, 1946). This approach values action as a mediator in the educational process, encouraging students to express themselves spontaneously and non-invasively in group settings. Such collective experience promotes critical reflection and knowledge reconstruction, thereby supporting meaningful learning.

The pedagogical use of psychodrama extends beyond its origins in clinical and social settings. When applied to education, it has been shown to foster empathy, cooperation,

creativity, and the integration of cognitive and affective domains (Romaña, 2010; Blatner, 1996). Empirical studies in different contexts have reported positive effects on communication and teamwork (Maya and Maraver, 2020), the development of reflective and critical thinking (Liberali and Grosseman, 2015), and increased motivation and engagement in learning activities (Nolte, 2025). From this perspective, educational psychodramafunctions as a model of embodied pedagogy, engaging physical action and emotional expression for the collective construction of knowledge (Bowman, 2014).

This perspective aligns with theoretical frameworks that shift the focus of learning from the teacher to the student, emphasizing action as a central component. For instance, Dewey (2022) argues that meaningful learning occurs when students engage with concepts and ideas through practical problem-solving (learning by doing) and social interaction. Reinforcing this idea, Vygotsky (1978) rejects a passive model of education, assigning play a foundational role in the learning process. Henry Wallon (Van der Veer, 1996) expands this perspective by suggesting that the educational process emerges from the integration of affective, cognitive, and motor domains.

A psychodramatic practice unfolds in three linear stages: warm-up, dramatization, and sharing. The warm-up prepares students (physically, emotionally, and mentally) for the dramatization by creating a safe and uninhibited environment. During dramatization, students engage with concepts concretely on a stage through dramatic forms such as dramatic games, role-playing, or spontaneous theater. Finally, the sharing stage invites students to reflect on the experience, enabling the internalization of learning and the construction of new knowledge.

In psychodramatic practice, students alternate between the roles of the protagonist (those performing the dramatization) and the audience (those observing and actively interacting with the scene). This entire practice is completed and overseen by the director (the teacher), who guides the practice with pedagogical intentionality by fostering attentive listening, expression, and active participation. To facilitate this guidance, the director leverages a repertoire of established psychodramatic techniques, including mirroring, doubling, and role reversal (Moreno, 1946).

Acknowledging that the use of psychodrama in school settings requires specific training (which remains limited among teachers), we adopted a deliberately simplified approach in our intervention. This choice aimed to make implementation feasible even for educators with only an introductory understanding of psychodrama. Based on that, our intervention design preserved key principles of psychodrama, including learning through action, psychodramatic stages and roles, perspective-taking through roles, and the integration of emotion and cognition.

In addition to the core psychodramatic structure, we incorporated structured dramatic games with role reversal and soliloquy techniques. Unlike less structured compositions (e.g., spontaneous theater or open-ended role-playing), dramatic games are defined as structured, playful activities designed to develop specific skills or attitudes. As participants (both students and teachers) lacked prior experience with open-ended formats requiring

them to generate scenes and conflicts, these structured dramatic games were the most pedagogically suitable option for this study.

Regarding the techniques used, role reversal allowed children to experience another's perspective during a game, fostering empathy and expanding their understanding of interpersonal relationships. Soliloquy, in turn, encourages protagonists to verbalize their thoughts and emotions during the dramatization, promoting emotional expression, autonomy, and insight into their reasoning processes. Together, these techniques operationalized the principles of action, spontaneity, and reflection that characterize psychodramatic learning.

4. Method

4.1 Participant Teacher Preparation

Teacher preparation began with two preliminary meetings involving the teachers, the pedagogical coordinator, and the principal. In the first meeting, we clarified the study's objectives, the intervention method, the researcher's support, and the Informed Consent Form (ICF). In the second meeting, we gathered information about the school context, curricular goals, the academic profiles of the fifth-grade students, and the teachers' lesson plans.

Based on this information, we designed and conducted four training sessions to equip the teachers with the necessary knowledge of CT, graph fundamentals, and educational psychodrama. The first session, lasting 90 minutes, introduced fundamental concepts of graph structure and CT, along with their integration into traditional subject areas. In the second session (two three-hour classes), we presented psychodrama principles and their educational applications through an immersive activity in which teachers experienced a psychodrama-based lesson. This experiential approach allowed them to internalize the method both conceptually and practically.

In the third and fourth sessions, we provided two 60-minute simulations for the teachers to practice our psychodrama-based intervention. Each session included an overview of the intervention's objectives, a simulation with peers in the role of students, and a reflection period to address questions, refine instructions, and reinforce key learning points. We discussed the teachers' role as directors in depth, highlighting the importance of encouraging student participation and independent thinking, and supporting learning without providing direct answers. Crucially, the training also focused on the function of the share phase (group reflection) as a mechanism for processing and reframing the socio-affective dynamics emerging from the dramatizations, particularly regarding feelings of preference or discomfort.

We provided teachers with comprehensive materials covering computational thinking (e.g., schematic summaries of CT concepts, interdisciplinary lesson plans), graph fundamentals, and educational psychodrama. At the end of the sessions, the teachers initially expressed uncertainty regarding the concepts and the nature of the intervention. However, they reported feeling more confident and motivated to apply our intervention after completing the training.

4.2 Pedagogical Intervention Design

We designed the intervention based on the pedagogical motivations discussed in Section 3.2. We later refined this initial proposal based on the teachers' suggestions that arose during the preparation process (Section 4.1) and certain aspects of the school context (Section 3.1). The intervention, titled "Bodies tangled like spaghetti," is detailed in Table 1.

Table 1. "Bodies tangled like spaghetti" Intervention

Objective:	To explore the concept of graphs as a means of representing objects and situations through network structures composed of elements (nodes or vertices) and their connections (edges). The objective is to engage students with key ideas such as connections between elements (adjacency), possible paths between nodes (traversals), and transformations within the network, including the addition or removal of elements and connections
Grade:	Fifth
Material:	Chalkboard, two or three rolls of yarn, string, or similar flexible materials
Location:	Classroom or another suitable outdoor area that can accommodate both the dramatization space (the stage) and the audience
Teaching Prerequisite:	Emotional, mental, and physical warm-up for the teacher. Development of the social atom of the student group. Previous fundamental concepts of algorithm and variable
Organizational Prerequisite:	Arrange the location by clearing a central area for the stage, with chairs placed at the edges to form a semicircle or a "U" shape. Cut the rolls into strips of 2 to 3 meters, ensuring each student receives two strips
Duration:	90 minutes
Moment / (Est. Time)	Objective and Expected Results
Nonspecific Warm-up (5 min.)	Engage in relaxation exercises modeled as "Stretching like a sleepy cat." This activity aims to help students release tension and disengage from external distractions, thereby preparing them to focus effectively on the lesson ahead
Specific Warm-up (30 min.)	Provide a visual introduction to the concept of graphs and their fundamental operations through everyday examples. The objective is for children to internalize the core concepts and processes of graphs and bridge these ideas to real-world or digital objects.
Dramatization (40 min.)	Construct the friendship network of the class. Students are expected to demonstrate mastery of all relevant graph concepts and operations through this tangible, experiential activity
Sharing (15 min.)	Articulate reflections on the experience and the concepts learned. Students are expected to critically evaluate their learning process and the understanding they have gained about graphs

The intervention “Bodies tangled like spaghetti” begins by shifting students’ attention from the external environment to the classroom interior, promoting mindfulness and present-moment focus (Moreno, 1946). This initial moment, referred to as the *Nonspecific Warm-Up*, involves a brief relaxation exercise guided by the teacher. To ensure freedom of movement, the teacher must space the students throughout the designated intervention area. Once seated comfortably, they maintain an upright posture with relaxed arms resting on their laps, balancing comfort with attentiveness.

The relaxation exercise begins with deep, slow breathing lasting two minutes. With eyes closed, students inhale deeply through the nose, hold briefly, and then exhale slowly through the mouth. Soft background music may enhance the calming atmosphere. Maintaining this relaxed state, the teacher then leads students through a guided visualization, imagining themselves as sleepy cats awakening and stretching slowly. In this sequence, they are prompted to extend their legs, then their arms, to spread their fingers, to move onto all fours, and finally to arch their backs. The teacher concludes by gently guiding them back to the original seated posture with smooth, deliberate movements. These exercises effectively soothe both mind and body, fostering greater concentration and increasing students’ receptivity to learning (Goleman, 2020).

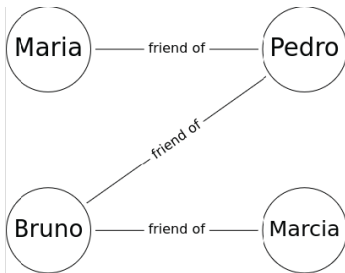
Following the initial preparation, during the *Specific Warm-up* moment, the teacher initiates a brief inquiry into the students’ understanding of friendship networks, a familiar and intuitive introduction to the concept of graphs. To prompt this discussion, the teacher asks: “Do you know who your friends are?” and “Do you know who your friends’ friends are?” Based on their responses, the teacher encourages further reflection: “Did you know that we can visually represent a network of all our friends and our friends’ friends?” Building on this context, the teacher introduces a simple network diagram representing the hypothetical friends of a character named “Pedro” (Figure 1(a)). During the presentation, the teacher highlights the network’s components: circles symbolizing individuals and lines representing friendship connections.

Using Pedro’s network as a reference, the teacher then guides students through a sequence of explanations, demonstrating the key operations for manipulating a friendship network (e.g., adding, removing, and inspecting connections) using the chalkboard or digital resources. To make this moment more engaging, we strongly recommend using a playful, emotionally expressive narrative style, with variation in vocal tone (e.g., rhythm, volume) to capture students’ attention and encourage active participation.

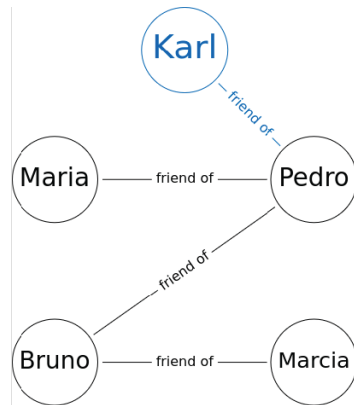
When introducing the addition of a new individual and their friendship with Pedro (a new node and a new edge, respectively), the teacher can actively engage the class by asking: “Everyone, Pedro has made a new friend! Karl! What changes should we make to the network?” After collecting the students’ responses, the teacher visually demonstrates the corresponding update to the network, highlighted in blue in Figure 1(b). Similarly, the formation of new friendships between existing members of the network can be explored with questions such as: “Maria has become friends with Karl and Bruno! How should we represent this in the network?” The educator gathers the students’ comments before visually showing the new edges added, as shown in blue in Figure 1(c).

To address operations involving friendship verification (that is, checking adjacency between nodes), the teacher prompts careful observation with questions like: “Is Pedro friends with Marcia according to our network?”, “What about Pedro and Bruno?”, or “Who are the mutual friends of Maria and Pedro?” The teacher reinforces students’ answers through visual aids, such as the blue ellipses in Figure 1(d), which emphasize that lines between nodes represent friendship connections, and the absence of a line indicates no established connection.

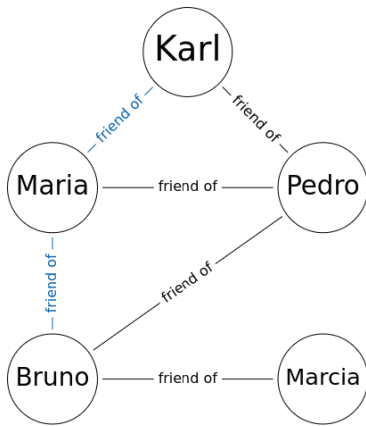
Continuing with the operations, the teacher captures the class’s attention by announcing that the two individuals are no longer friends: “Oh no, Pedro and Bruno disagreed and are no longer friends! What happens now?” After gathering the students’ responses, the teacher demonstrates the removal of the edge, indicated by an X in Figure 1(e). During this demonstration, the teacher underscores that the individuals remain part of the network, and only the connection between them is removed, as highlighted by the ellipse in Figure 1(f). Subsequently, the teacher states, “Marcia is no longer friends with Bruno and will leave the network! How does this affect Pedro’s network?” After soliciting students’ answers, the teacher illustrates another removal operation: an individual exiting the friendship network.



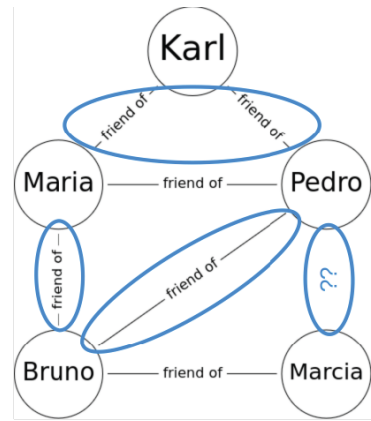
(a) initial graph



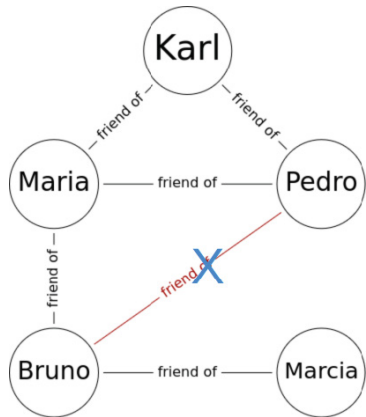
(b) edge and node addition



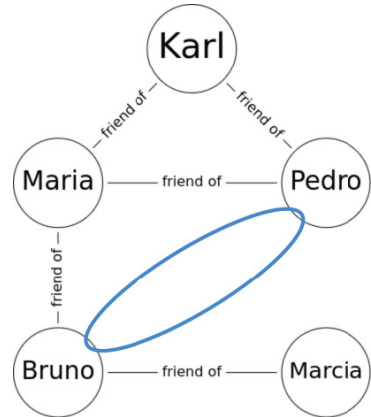
(c) edge addition



(d) check adjacency



(e) edge removal



(f) after edge removal

Fig. 1. Elementary Operations on the Friendship Network (Graph) – Part I)

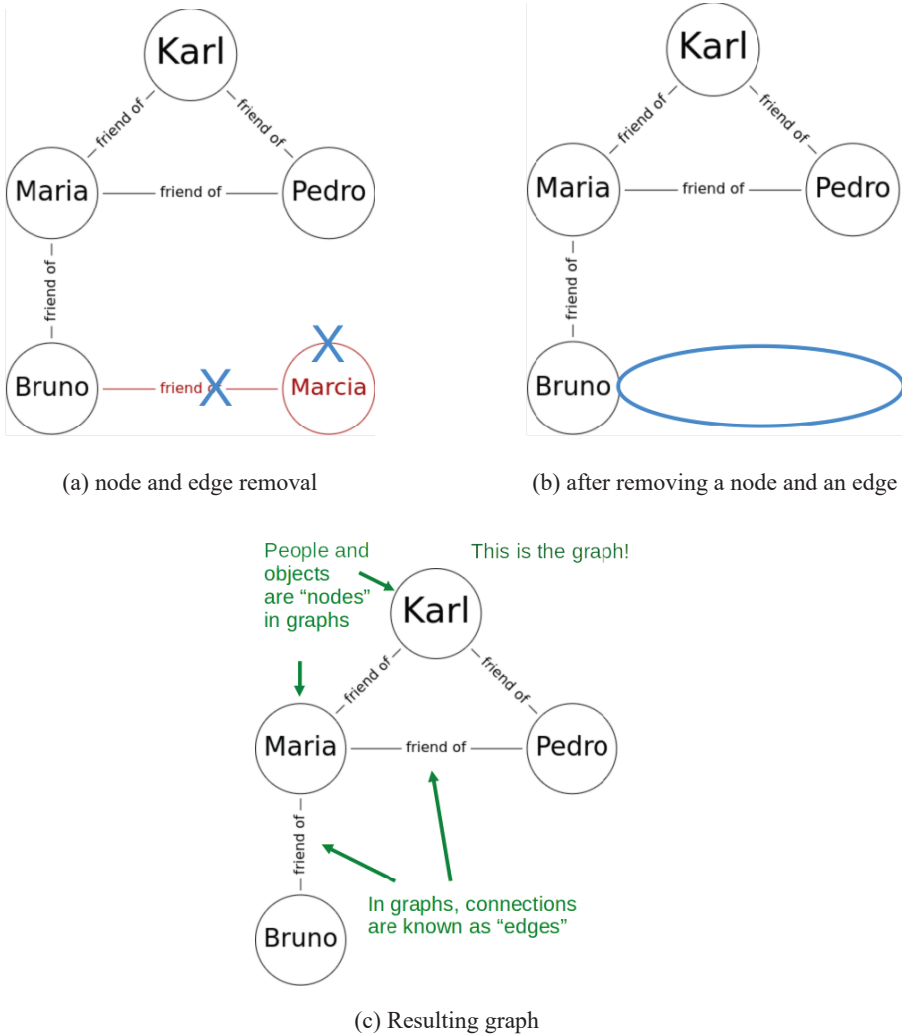


Fig. 2. Elementary Operations on the Friendship Network (Graph) – Part II

This operation is also marked with an X in Figure 2(a). However, unlike the previous case, this operation requires removing both the person and all their associated connections, as depicted by the ellipse in Figure 2(b).

The teacher concludes the specific warm-up by presenting the final version of the friendship network of the character “Pedro” (Figure 2(c)). The educator explains that this representation has the curious name of “graph,” a structure widely used to represent connections among various types of objects. Subsequently, the teacher highlights that the graphs consist of two essential elements: nodes, which represent objects, and edges, which connect the nodes. To make the concept more concrete and relatable to students’ daily lives, the

teacher presents well-known examples of graphs, such as the representation of the São Paulo metro lines, the tables of World Cup matches, among others. In the context of computers, he reinforces that graphs are essential for representing complex relationships, such as those found in social networks, for example.

At the following moment, the *Dramatization*, all students become protagonists, concretely experiencing the concepts introduced in the previous moment within a context close to their reality. Since each student actively participates in constructing the friendship network, there is no audience. To initiate the activity, the teacher arranges all students in a large circle and introduces the task of creating the class friendship network. Following a predefined order (e.g., alphabetical), one child is selected and receives two strings. They then choose two classmates with whom they wish to establish friendship connections. For each chosen peer, they walk toward them, offering one end of a piece of string while holding the other. Once the connections are established, the student returns to their place in the circle, as illustrated in Figure 3. This procedure continues until all children have represented their friendship connections. As an alternative to the form described above, the teacher may manage ribbon distribution to avoid confusion as the network expands.

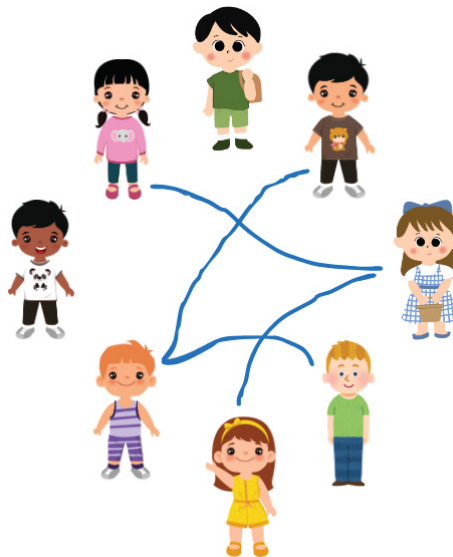


Fig. 3. Illustrative example of the friendship network construction

Methodologically, the number of connections was limited to a maximum of two nominations per student, a design choice driven primarily by constraints of classroom dimensions and the total number of participants. Crucially, this limitation served a pedagogical purpose: it required students to engage in a selective, reflective process of nomination, thereby emphasizing the concept of intentional connectivity within the graph structure. Although

selection could potentially introduce discomfort, our choice to adopt educational psychodrama, which is fundamentally equipped to handle and process socio-affective dynamics and potential exclusion (Blatner, 1996), ensured that any emergent feelings were immediately addressed through structured group reflection during the intervention itself. The observed dynamic was predominantly one of inclusion rather than exclusion.

Once the friendship network is complete, the teacher invites the children to explore and observe basic network operations. To facilitate this guided exploration, we suggest questions similar to those shown in Table 2, where uppercase letters represent student names. Following each response, the teacher reinforces the children's reasoning by encouraging them to physically and playfully represent the relevant elements of the friendship network (nodes and edges). For example, students may gently raise their arms while holding the string to represent friendship connections (edges) or raise their arms without ribbons to represent individual classmates (nodes).

Table 2. Guiding questions for the exploration of the friendship network graph

Question
E1 -Who are W's friends?
E2 -Who are the mutual friends of X and Y?
E3 -What happens if classmate T is removed?
E4 -What happens if A and B are no longer friends?
E5 -What happens if C and D become friends?

After the experimentation, the *Sharing* moment initiates, enabling students to collectively reflect on, discuss, and make sense of their experiences. The teacher invites all students to return to their seats and explains that the class will reflect on the insights gained during the construction of the friendship network. To facilitate this reflection, the teacher utilizes guided questions (see suggested prompts in Table 3) that foster critical examination and articulation of students' experiences.

It is recommended that students work in small groups of three to four members to address the challenging question R5, depict their solutions as graph structures on paper, and subsequently present them on the board. This challenge facilitates a connection between the experiential learning during dramatization and the formal visual representation of graph structure, thereby reinforcing the conceptual foundations introduced earlier and illustrated in Figure 2(c). After the discussion, the teacher formally closes the intervention by expressing gratitude to all participants and underscoring the activity's primary objective: to offer an introductory comprehension of graphs, their operations, and their significance within both computational frameworks and real-world contexts.

Table 3. Guiding Questions to Foster Reflection

Question
R1 -What emotions did you experience during the construction of the network?
R2 -Which operation on the network did you find the most challenging?
R3 -What was the most surprising thing you learned?
R4 -How can you apply what you have learned to situations in your daily life?
R5 -Do you think all friendships carry equal importance in your network? How might you represent stronger and weaker friendships in your graph?

As observed, the intervention is self-focused in preparing students to engage in and withdraw from the experience with mindfulness and awareness. Nonetheless, it is essential to emphasize that a preparatory phase precedes the intervention (denoted as “Teaching Prerequisite” in Table 1), involving both the teacher and the entire student group.

When leading psychodrama-based interventions, the teacher must be emotionally, mentally, and physically prepared to connect with the student group from the warm-up onward and to guide the intervention with confidence and clarity (Moreno, 1946; Blatner, 1996). This preparation is achieved through a pre-warm-up routine conducted before the intervention begins, addressing one or more of these dimensions based on the teacher’s self-assessment. Physically, the teacher may engage in stretching exercises, deep breathing, or free-form body movements set to gentle music to promote relaxation. Mentally, reading an inspiring passage or visualizing the role to be performed during the intervention can strengthen motivation and stimulate spontaneity. Lastly, dedicating several minutes to meditation, mindfulness practices, or visualizing a successful session can support emotional equilibrium.

For students, cultivating a network of interpersonal bonds rooted in camaraderie, shared affinities, and mutual respect is essential, referred to by Moreno (1946) as the “social atom.” A lack of these interpersonal bonds can hinder the success of psychodramatic interventions, given that insecurity and mistrust often reduce students’ capacity for spontaneous engagement. In low-cohesion groups, particularly when there has been limited prior interaction among participants, students are less likely to feel sufficiently safe to share their knowledge and uncertainties openly and spontaneously. Additionally, students are expected to possess a foundational understanding of algorithms (sequences and single repetitions) and variables, previously explored in a playful context as outlined in (Josko and do Amaral, 2025).

4.3 Data Collection Framework

Due to restrictions on capturing images, recording videos, or conducting student interviews, we adopted an ethical and non-intrusive approach to gather information on student engagement, collaboration, and learning outcomes. Our data collection strategy combined qualitative and quantitative methods, employing three instruments: *teachers' interviews*, an *assessment activity*, and the *researcher field notes*.

To conduct the interviews, we employed a semi-structured approach, which balances the use of preplanned questions with the flexibility to introduce new ones in response to unexpected or contradictory answers. Table 4 outlines the set of questions designed to elicit insights aligned with the objectives of this study. Each interview lasted approximately thirty minutes and took place in a quiet environment within three days following the intervention. We adopted a warm and respectful tone, ensured smooth transitions between questions, and encouraged participants to elaborate on their responses without applying pressure or interrupting them. All interviews were audio-recorded, and to ensure the reliability of the data, we invited teachers to validate the transcripts. When necessary, we added complementary notes to clarify ambiguous statements, highlight key points, capture impressions, and contextualize the interviewees' verbal and non-verbal expressions.

Table 4. Guiding Questions for Teacher Interviews

Perspective	Question
The Teacher	I1. Please describe your overall experience and feelings while conducting the educational psychodrama-based intervention
	I2. What were the primary challenges you faced during the intervention's conduct?
	I3. What modifications or improvements would you recommend for the intervention?
The Students	I4. To what extent did you observe active student engagement throughout the intervention?
	I5. After the intervention, did you notice any cognitive, emotional, or behavioral changes in the students? Please elaborate
	I6. In your assessment, how well did the students grasp the concept of graphs? Please provide specific examples
The Method	I7. Would you consider using psychodramatic pedagogy for other curricular topics? Why or why not?

In the assessment activity, the children responded to four open-ended questions based on the context of connecting public buildings in the fictional town of Connectville (Figure 6). Aimed at measuring the retention of graph concepts, the evaluation was administered by the teachers four weeks after the psychodramatic intervention, without the presence of the researcher. The first question (Q1) focused on identifying adjacency relationships based on the town's original layout. Question Q3 also addressed adjacency, but in the context of single-edge removal. Finally, questions Q2 and Q4 assessed students' understanding of graph traversal, requiring them to analyze changes to the city's network following the removal (Q2) and addition (Q4) of one edge between buildings.

Finally, for the *researcher's field notes*, we employed the observation technique to document facts, events, and spontaneous behaviors within natural social settings, such as the classroom context (Cohen et al., 2002). Observations may follow a structured approach (e.g., focusing on pre-defined events), an unstructured approach involving open-ended descriptive notes, or a semi-structured approach that combines elements of both (Cohen et al., 2002). In this study, we employed a semi-structured approach to balance systematic tracking with the flexibility needed to capture emergent insights.

We conducted 90-minute observation sessions with two fifth-grade elementary school groups. Group T 1 consisted of 21 students (11 girls and 10 boys), and group T 2 consisted of 20 students (10 girls and 10 boys), totaling 41 participants. The researcher maintained a detached observer role to minimize disruption. For the structured observations, we employed a table sheet divided into three-minute intervals and predefined markers specific to this work (Table 5) to track engagement patterns, participation, and the application of learned concepts. For the unstructured observations, we documented unexpected events (e.g., spontaneous moments, movements, interesting insights from students) and recorded transitions between the intervention's moments in a notebook. We used these transition annotations to adjust the five-minute intervals, refining the temporal representation of intervention moments in Figure 4. An expanded observational analysis was subsequently conducted.

We recorded structured observations at three-minute intervals because this duration was optimal for capturing stable patterns of student behavior during classroom activities while balancing detail and practical feasibility in a dynamic environment. Shorter intervals could have overwhelmed the single researcher acting as the observer, whereas longer intervals risked missing key moments of transition or heightened engagement. Unstructured transcriptions were completed immediately after unexpected events and were later supplemented with additional reflections.

Table 5. Predefined Markers for Structured Observations

Theme	Code	Evidence
Express positive or negative bodily, emotional, or behavioral indicators related to ENGAGEMENT during the various moments of the intervention	PEE1	Positive emotional expressions during the intervention (e.g., smiling, laughter, enthusiasm, surprise, satisfaction)
	PEA1	Active commitment to interaction and cooperation with peers to complete tasks
	PEA2	Relevant contributions (e.g., questions, comments) during the intervention
	PEA3	Attentive listening to peers or the teacher, demonstrated through appropriate eye contact and posture
	NEB1	Mechanical bodily movements or gestures, or withdrawn posture (e.g., crossed arms, lowered head, fidgeting, swinging legs), revealing a poor relation to the intervention moment
	NEE1	Negative emotional expressions during the intervention (e.g., blank facial expression, looking down, sadness, apathy, boredom, irritation)
	NEA1	Minimal or mechanical interaction with peers during task completion
	NEA2	Disinterest in listening or contributing, including side conversations or inappropriate interruptions
Express positive or negative bodily, emotional, or behavioral indicators related to APPROPRIATION (mastery) of the learned concepts during the various phases of the intervention	PUE1	Emotional expressions of confidence and enthusiasm when applying the concepts
	PUA1	Communicative gestures (e.g., pointing), practical actions (e.g., moving objects), or representations demonstrating accurate conceptual understanding
	NUE1	Emotional expressions of frustration, discouragement, uncertainty, or disinterest when applying the concepts
	NUA1	Communicative gestures (e.g., pointing), practical actions, or representations demonstrating misunderstanding or incorrect application of concepts
Show positive or negative bodily, emotional, or behavioral indicators related to REFLECTION	PRE1	Confident communication regarding learning or experiences during the intervention, articulated alongside perceived feelings
	PRA1	Presentation of constructive opinions about aspects of the intervention or relevant additional comments
	NRE1	Resistance or insecurity when communicating about learning or experiences during the intervention
	NRA1	Limited, superficial, or absent participation concerning aspects of the intervention or peers' and teachers' viewpoints

4.4 Data Analysis Procedures

We conducted the data analysis in three stages to ensure alignment with the research question outlined in the introduction. First, we organized the data by type (field notes, teacher remarks, and assessment activity results) and by class. Handwritten student responses were transcribed and digitized to facilitate processing with qualitative analysis software. Next, we refined the unstructured observations by eliminating duplicates and clarifying ambiguous text.

Finally, we analyzed the observation data through deductive coding (Saldaña, 2013), using the predetermined categories defined in Table 5 (e.g., engagement and participation). These codes provided a structured basis for systematically identifying and analyzing behavioral patterns throughout the intervention. In contrast, the teacher interviews were analyzed using inductive Thematic Analysis (Braun and Clarke, 2006). After familiarization with the transcripts, we carried out meaningful phrase coding, grouped similar codes, and refined them into broader themes that captured recurring perceptions related to student engagement, conceptual appropriation, and the pedagogical value of the psychodrama-based intervention.

To analyze student performance beyond a simple dichotomous (correct/incorrect) measure, we employed a pattern-based scoring method suitable for the assessment questions' simple, constrained nature. We developed a straightforward classification rubric based on explicit, observable patterns in the responses, which generated the response codes listed in Table 6.

It is important to note that a second coder was not employed at this stage because the analyzed texts were brief, tightly guided by predetermined questions (as in the interviews), and required situated interpretation. These factors substantially minimized interpretive ambiguity, resulting in more objective coding with reduced susceptibility to subjective variation. Consequently, the application of intercoder agreement procedures, as recommended by Saldaña (2013), was deemed unnecessary.

In the final stage, we produce detailed tabulations and visualizations (bar charts and temporal scatter plots) of the structured observations (see Table 5), capturing behavioral trends over time. These visual tools effectively revealed the intervention's key features, including code frequencies and cross-class pattern correlations. Moreover, they facilitated the seamless integration of qualitative data (unstructured observations and teacher interviews) with quantitative student assessment results.

To ensure interviewee anonymity, we applied a narrative composition technique that constructs coherent narratives from participant statements (Johnston, 2024). In the Results section, excerpts derived from these composite narratives are integrated with the observational data to illustrate teachers' perspectives on each intervention phase, thereby maintaining consistency between the data sources and providing contextual insight into the implementation process.

5. Results

Figure 4 illustrates the structured observations collected during the lesson periods of the fifth-grade classes (T1 and T2), highlighting the distinct intervention's moments (Table 1). The shaded areas indicate the duration of each moment, beginning with pastel blue (first area) for the Nonspecific Warm-Up and concluding with pastel red (fourth area) for the Sharing phase. The following sections present a detailed analysis of each intervention moment, providing a clearer understanding of the dynamics of engagement and learning.

5.1 Observational Results

During the *Nonspecific Warm-Up* (Figure 4, first area), we observed substantial engagement across both classes, with broad participation in a highly enjoyable context (PEE1).

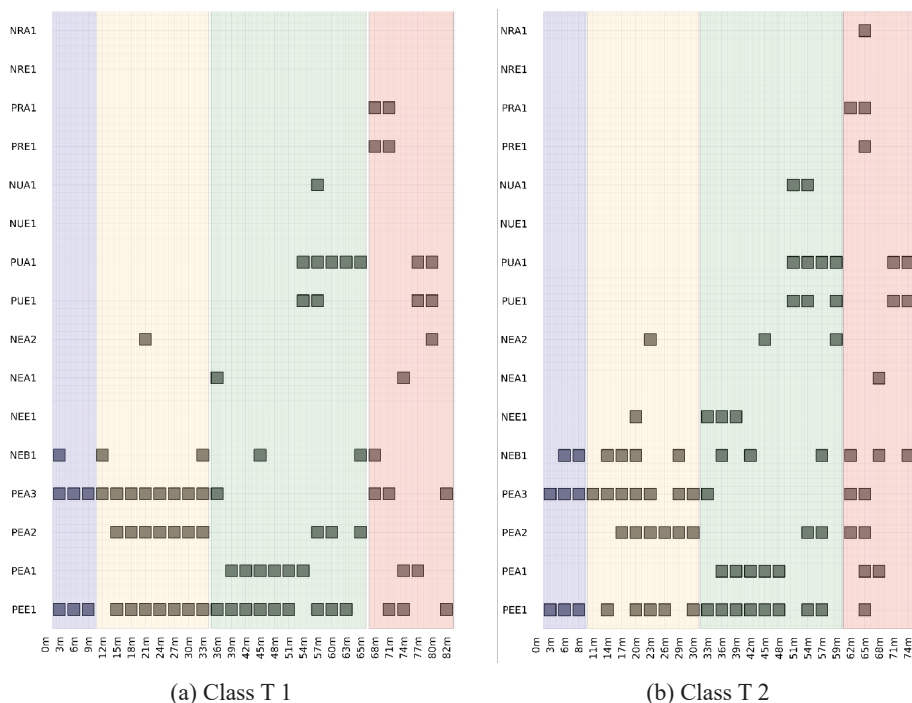


Fig. 4. Temporal representation of structured observations by code and intervention moment

The relaxation exercise was compelling. Most children exhibited serene facial expressions and relaxed postures while attentively following the teacher's instructions, conveyed in a warm and gentle tone (PEA3). However, two or three students from class T2 appeared more interested in handling their school supplies during the relaxation period (NEB1).

Nonetheless, all students remained calm and attentive during the transition between the end of the relaxation and the beginning of the specific warm-up, which indicated their

readiness to engage in the lesson experience (Weare, 2013). This pattern indicates strong initial engagement, suggesting that the warm-up phase successfully prepared students affectively and behaviorally for the learning experience, addressing the first dimension of the research question.

From the beginning of the *Specific Warm-Up* (Figure 4, second area), the children demonstrated interest in the lesson topic, actively participating in both the manipulation exercises and the discussion of the questions introduced by the teacher. Students also spontaneously contributed additional real-life examples (e.g., social networks) in which they recognized the presence of graphs (PEA2, PEA3, PEE1).

Most children accurately described the effects of the operations on the friendship network used as an example, frequently using eye movements and hand gestures in the air to indicate the affected sections on the board. A few children preferred to take notes in their notebooks. However, they also used the same strategy (focused gaze and pointing gestures) to carry out the operations. These behaviors show not only engagement but also early signs of conceptual appropriation, as students relied on gestures and spontaneous examples to reason about adjacency and connection.

An intriguing example of engagement was observed during the explanation of the elementary operations on the sample graph. Children from both classes spontaneously raised various scenarios (e.g., “It looks like Bruno is causing problems,” “Why didn’t Marcia become friends with Pedro?”), revealing concern for the characters in Pedro’s friendship network and demonstrating active reasoning. However, a small group of students from class T2 showed signs of fatigue or distraction during these discussions (NEB1, NEE1), in contrast to the brief moments of inattention observed in class T1. The fact that this intervention took place during the last two lessons of the day (following a celebration held earlier) may have contributed to this behavior in T2.

The beginning of the *Dramatization* (Figure 4, third area) was marked by a low murmur, accompanied by expressions of displeasure from two isolated students in class T2 (NEE1). Following the teacher’s initial mediation and presentation of instructions, the first selected students struggled to establish the intended connections. As the number of connections progressively increased, the teacher began assisting in consolidating the links. Throughout the activity, cooperative behaviors and evident satisfaction were observed among the children in both classes as they developed and maintained the friendship network, along with a willingness to assist peers who experienced difficulty manipulating the strips (PEA1, PEE1). This collaborative environment and focus on relational action were structurally reflected in the resulting friendship graph, which showed a nonconcentrated relationship distribution (i.e., no single student or small group was overwhelmingly chosen as a central node), thus highlighting the successful socio-affective outcome of the activity.

The children responded fully to the questions designed to explore the classroom friendship network (Table 2). We observed that they carefully examined the class friendship graph and then raised their arms with enthusiasm and in a collaborative manner to represent the connections relevant to each question (PUA1, PUE1). An interesting aspect was the

deliberate organizational strategy demonstrated by the students, who took care to hold the specifically selected strips in one hand before responding to the teacher's questions. However, four incorrect friendship connections were indicated (NUA1): three were promptly corrected by the students themselves (two in class T1 and one in T2). However, a single occurrence of this incorrect connection was missed by both the students and the teacher in class T2. The ability to physically manipulate the network and collaboratively correct errors directly demonstrates the appropriation of adjacency and modification concepts, addressing the second dimension of this work's research question.

During the *Sharing moment* (Figure 4, fourth area), most of the children expressed enthusiasm and energy as they contributed their reflections on each of the proposed questions (PRE1, PREA1). These contributions were accompanied by attentive and joyful expressions from their peers (PEA3, PEE1). In contrast, a few appeared distracted and unwilling to cooperate (NEB1, NEA1). Among the various responses, a considerable number of children identified holding the strip as the most challenging aspect of the activity (R2). The accumulation of discarded strips on the floor resulted in a tangle near the children's feet, which diverted the attention of some as they attempted to untangle the material. The errors observed during the dramatization appeared to result not from conceptual misunderstanding but from the motor complexity involved in handling the strings, as students often demonstrated understanding verbally while struggling with the physical manipulation. The physical requirement of maintaining a connection with classmates while simultaneously raising their hands to respond led to momentary confusion for some participants. For future implementations, we recommend that the strips be mounted on reels (or comparable supports) to improve ease of handling and minimize potential disruptions.

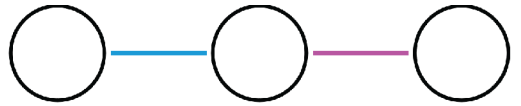
Another notable response was the surprise expressed by many children upon concretely visualizing the established classroom friendship network and recognizing connections they had not previously perceived as existing (R3). For example, some children remarked, "It was nice to see who is friends with whom," and "I didn't even know that x was friends with y !" Finally, possibly influenced by the discussion around the loss of connections in the character Pedro's network, several children expressed an intention to avoid conflicts over trivial matters (R4), aiming to preserve their friendships.

The most significant moment during the Sharing moment involved the children's engagement with question R5, which aimed to stimulate conceptual reflection and the creative transfer of newly acquired knowledge about graphs (PEA1). The eleven student groups proposed various ways to represent the strength of friendships within each class's friendship network. Their responses were spontaneous and relied exclusively on the materials explored during the lesson (strings, connections, nodes), without any prior introduction of formal concepts such as "weighted graphs." As a result, four distinct strategies emerged: differentiation by the color of the connection (a), by the length of the connection (b), by the shape of the connection (c), and by the size of the node (d), respectively illustrated in Figure 5.

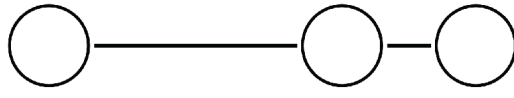
The first and fourth strategies were the most and least frequently represented by the chil-

dren, respectively ($\frac{5}{11}$ and $\frac{1}{11}$). Although these representations do not encompass all the formal possibilities of graph theory, they reflect a genuine problem-solving process: the children extended the examples presented, applied knowledge creatively, and adapted graph representations to a new context (PUA1). The nature of the responses indicates that the students went beyond prior knowledge and generated an original solution by adapting the graph structure to a novel situation, thus demonstrating meaningful appropriation of the content (Josko, 2023). For instance, one student proposed enlarging certain nodes to indicate the “importance” of specific friendships. While this is not a formally correct graph representation from a mathematical standpoint, it reveals an intuitive attempt to extend the representational system to encode the strength of social connections. In this pedagogical context, such an action illustrates an early form of symbolic abstraction rather than a misconception.

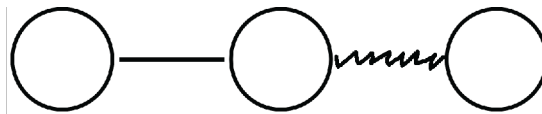
The children’s comments, emotional insights, and creative attempts to extend the representation system indicate reflective thinking about both the social and structural aspects of graphs, addressing the third dimension of the research question.



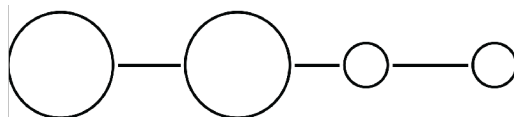
(a) Differentiation by the color of the edge



(b) Differentiation by the length of the edge



(c) Differentiation by the shape of the edge



(d) Differentiation by the size of the node

Fig. 5. Proposals for categorizing friendships by importance

5.2 Interview Results

Our teachers' interview analysis revealed three main themes related to our psychodrama-based intervention: *pedagogical value of the nonspecific warm-up, students' engagement and conceptual understanding, and the challenges and adjustments during the dramatization.*

Regarding the first theme, educators emphasized that the nonspecific warm-up moment was central to preparing both students and themselves. For instance, they reported that the "sleepy cat" exercise helped create a relaxed and open atmosphere, which improved the class's readiness before the content-focused moments. Teachers also observed that, unlike their usual lesson openings, this warm-up moment served as a means for them to mentally prepare by intentionally combining emotions and attention. The next composite narrative captures their perspectives on this intervention moment:

The relaxation with the story about the cat before the lesson was very agreeable. In addition to calming the children and aligning them with the lesson, this resource also served as a form of mental preparation for us, the teachers. Unfortunately, we have not organized ourselves sufficiently to carry out the prior preparation suggested by the intervention.

Regarding student engagement (the second theme), teachers consistently reported high levels of enthusiasm, curiosity, and emotional investment throughout the intervention. They specifically noted how the storyline of Pedro's friendship network captured the children's attention, leading to confident demonstrations of graph operations. Teachers also highlighted the pupils' conceptual retention, noting that some students later recognized diagrams in their textbooks as graphs. Furthermore, they expressed surprise at how easily students understood adjacency and modification after the dramatization, describing the children as significantly more confident than the teachers themselves when explaining the operations. These key perspectives are elaborated upon in the two subsequent narratives.

The situation and evolution of Pedro's friendship network appeared to capture the children's attention and also motivated them to engage with every question presented. At this age, the theme of friendship is highly relevant, especially since many are already familiar with social networks. Furthermore, the children appeared more confident than we were in describing the results of the operations on the graph. We felt somewhat apprehensive about making mistakes in our explanations, as graph is not a familiar topic for us.

It was rewarding to see that the children were eager to share their insights and what they had learned at that moment. This level of participation differed from the summaries we usually conduct at the end of a traditional lesson, where many children barely remember the first topic discussed. Additionally, it was interesting to observe that, in subsequent classes, some children began associating images or diagrams from the textbook with the concept of graphs. I believe this reflects the seeds planted by the intervention.

In the third theme, teachers described the challenges they faced during the dramatization. Specifically, they noted that handling multiple strips of yarn caused some students to divert their attention from the activity to handling the strips themselves. This situation made teachers suggest alternative materials or clearer procedures for distributing connections. However, they recognized the usefulness of educational psychodrama, indicating willingness to consider its use in other subjects due to its motivational effect and ability to engage students as a whole.

We noted that handling the yarn connections was more difficult than anticipated. At certain moments, the strings became tangled, creating confusion among some kids. We also experienced a pedagogical role shift: our primary work became ensuring the smooth flow of the scenes and maintaining the children's connection to the storyline. In other words, they were the protagonists, and we were more like facilitators of the action. This was new for us and sometimes demanding, requiring us to prioritize the groups' rhythm rather than delivering the content. Despite these challenges, we feel that the activity has potential and we would certainly consider using a similar approach again in future classes.

In synthesis, these teacher perspectives reinforce that the intervention promoted robust engagement, supported the appropriation of basic graph concepts, and facilitated reflective discussions, directly addressing all dimensions of the present work's research question.

5.3 *Extended Observational Notes*

In our extended notes, we identified additional relevant aspects regarding the intervention and its participants. One of these refers to the intuition demonstrated by the children as they manipulated and observed the transformation of the friendship network. The presentation of the graph in a spatial configuration (initially through a diagram and subsequently in its tangible form) provided a concrete and effective representation to communicate and explore interpersonal relationships, thereby significantly facilitating their understanding (Bobek and Tversky, 2016). We observed this intuition in the children's responses to exploratory questions posed during the dramatization, particularly when indicating the strips involved in the connections. Furthermore, we observed the same intuition during the specific warm-up phase, where some children verbally anticipated the effects of scenarios proposed by the teacher on the friendship network of the character "Pedro." This naturalness in graph manipulation suggests meaningful conceptual appropriation, as students were able to predict structural consequences in the graph without relying on formal terminology.

A second relevant aspect concerns the potential emergence of uncomfortable situations during the collective construction of the classroom friendship network. During the dramatization, we identified the possibility that a child might, for various reasons, refuse a friendship connection proposed by another child. For the child whose offer of friendship is rejected, such an episode could generate feelings of frustration and sadness, potentially leading to demotivation or refusal to participate in the activity (Rubin, 2011). Although this situation did not arise in the observed classes, we identified a gap in our guidelines:

we provided no specific instructions to the teacher on how to prevent or manage such occurrences.

Because the dramatization naturally involved choosing “friends” as part of the activity, we were attentive to possible discomfort or exclusion. In practice, such situations did not lead to visible distress, likely because of the teacher’s active mediation, which is a central element of psychodramatic practice. The teacher’s role as director ensured that group interactions remained supportive and inclusive, guiding the dramatization to maintain a constructive and safe atmosphere.

For future implementations, we suggest an alternative to broaden the concept of connection by encouraging children to establish bonds based on shared interests (e.g., sports, music, digital games, and cartoons) expressed at the beginning of the dramatization. By broadening the focus beyond friendship to include the identification of shared affinities, the network construction fosters a more inclusive and welcoming experience for all participating children.

5.4 Quantitative Results

While the qualitative data provided a deeper understanding of the children’s engagement, concept usage, and reflections, the quantitative analysis presented below allowed measurement of the extent of this understanding during the Connectville town assessment activity, illustrated in Figure 6. It is noteworthy that approximately 85% and 95% of students from classes T 1 and T 2, respectively, were present on the day of the assessment.

Figure 7 summarizes the frequency (y-axis) of the categorized response codes extracted from the answers given by the two student groups (T 1 and T 2) for the four evaluated questions (Q1 to Q4). These response codes, listed in Table 6, are shown on the x-axis. The shaded areas segment the bars representing the analysis of students’ responses for each question Q1 to Q4. This disposition aims to allow visual comparison of the frequency distribution of response codes between Q1 and Q4.

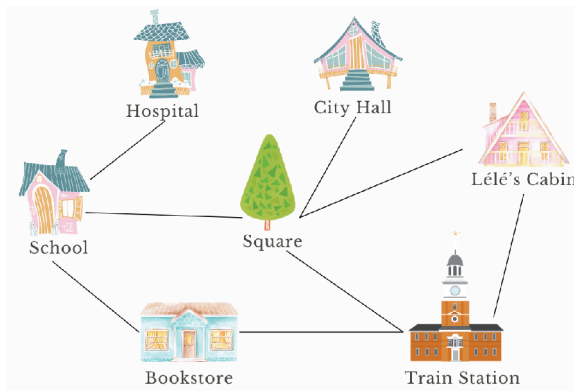


Fig. 6. The Connectville Graph utilized for the Assessment Activity

Table 6. Categorized Response Codes extracted from Assessment Activity Answers

Question	Code	Description
Q1	3nod	Correctly identified all three adjacent nodes
	2nod	Identified two of three adjacent nodes
	1nod	Identified one of three adjacent nodes
	Incnod	Incorrect nodes provided or response was omitted
Q2	2pat2	Correctly identified both required paths
	1pat2	Identified one of two required paths
	Incpat2	Incorrect paths provided or response was omitted
Q3	OK	Correctly identified adjacent nodes and provided explicit reasoning
	NotOK	Incorrect nodes provided, response was omitted or reasoning was absent
Q4	2pat4	Correctly identified both required paths
	1pat4	Identified one of two required paths
	Incpat4	Incorrect paths provided or response was omitted

The quantitative results revealed a distinct pattern of differential concept mastery linked to cognitive load. Regarding the single-step adjacency relationships question (Q1), which required students to correctly identify all three possible adjacent constructions (3nod), the results indicate a pattern of partial concept appropriation. While children exhibited an average accuracy of 48% ($SD = 0.21$), the full range of responses indicated a uniform attempt to solve the problem (no incorrect or omitted answers), with the score reflecting the prevalence of partial correctness. Specifically, a review of the responses showed that 14% of students correctly identified two of the three adjacent buildings (2nod), and 38% identified one correct building (1nod).

In contrast, the questions focused on identifying paths between buildings (Q2 and Q4) revealed a conceptual barrier. The precise accuracy (identifying both required paths) dropped to 45% ($SD = 0.25$) for Q2 (2pat2) and 33% ($SD = 0.08$) for Q4 (2pat4) on average. However, these accuracies increase to 62% and 86%, respectively, when considering students who correctly identified at least one of the paths (1pat2, 1pat4). This outcome is particularly notable given that the questions required multiple steps of decomposition, recognition, and abstraction before a solution could be formulated.

The other adjacency question, Q3, which required a structural modification (an edge removal), showed notable resilience in student performance. The success rate for it was 54% ($SD = 0.02$), nearly comparable to the simpler item Q1. Of the incorrect responses (46%), a significant portion (an average of 16.7%, $SD = 0.006$) refers to cases in which students

correctly identified the adjacent building but failed to provide the required explicit justification. We considered these cases to be incomplete.

A comparison of the two groups indicates that the overall differences in performance between the intervention conditions were modest and did not exhibit a consistent directional pattern. Group T 2 demonstrated a slight advantage on the foundational adjacency item (Q1) and on the initial traversal task (Q2). In contrast, performance on the second adjacency question (Q3, involving edge removal) was effectively equivalent across groups. Moreover, Group T 1 achieved a marginally higher success rate on the most complex item, the second traversal question (Q4). This absence of systematic or substantive divergence suggests that the core components of the psychodrama-based intervention yielded broadly comparable learning outcomes for both participating groups.

Despite only partial mastery, the ability to apply graph concepts in a non-embodied task after a significant delay provides evidence of learning transfer and directly addresses the second dimension of the research question. Considering the exploratory nature of this work and the cognitive demands involved, these outcomes are encouraging and educationally meaningful.

Although the accuracy rates observed across questions Q1 to Q4 may appear modest, they should be interpreted within the specific context of this study. The participating students had no prior instruction in graph theory or related data structures, and the tasks required them to transfer knowledge acquired through embodied dramatization to abstract, symbolic representations administered four weeks later. From this perspective, the results indicate an initial conceptual appropriation rather than mastery. They demonstrate that students were able to engage in basic reasoning about adjacency and traversal, demonstrating early manifestations of computational thinking processes such as abstraction and decomposition. Despite only partial mastery, the ability to apply graph concepts in a nonembodied task after a significant delay provides evidence of learning transfer and directly addresses the second dimension of the research question. Considering the exploratory nature of this work and the cognitive demands involved, these outcomes are encouraging and educationally meaningful.

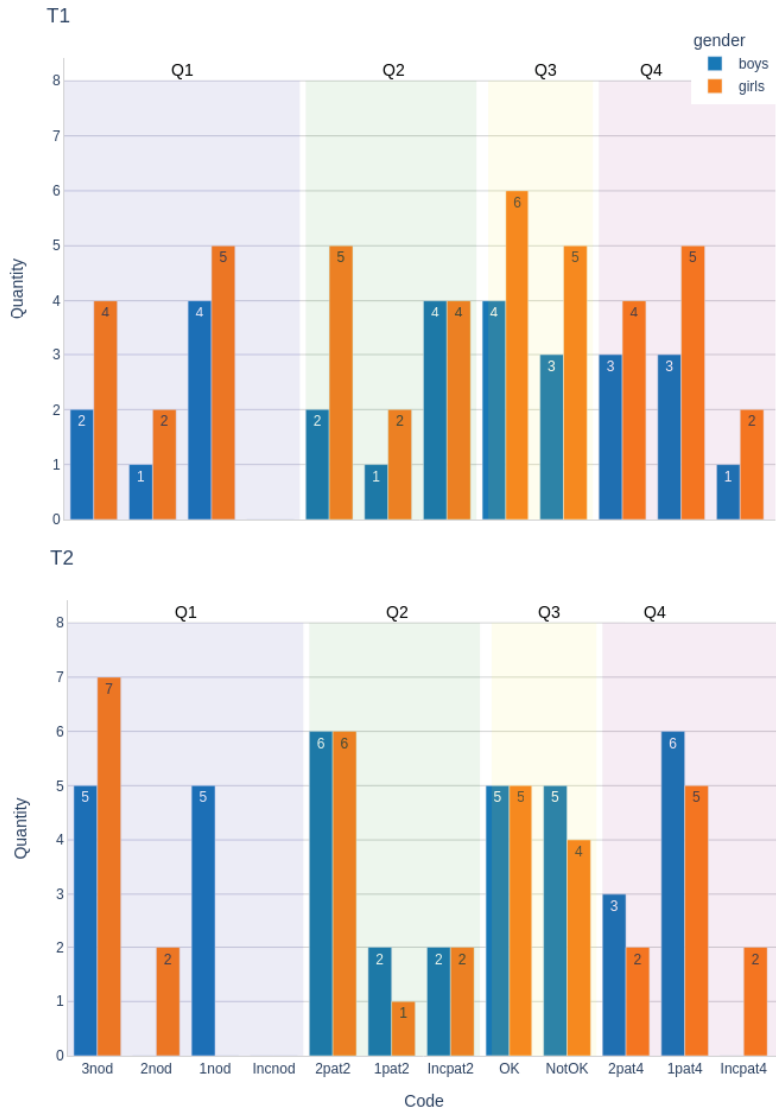


Fig. 7. Classification of Responses to the Assessment Activity by Question

6. Discussion

The results of the “Bodies tangled like spaghetti” intervention demonstrated the potential of educational psychodrama as a pedagogical approach for introducing fundamental graph theory concepts to elementary school children. This potential emerges from the three core dimensions examined in this study: student engagement, conceptual appropriation, and the development of critical reflection.

Student engagement was evident throughout the various stages of the intervention, particularly during the dramatization and sharing phases. This involvement was marked by expressions of enthusiasm, active cooperation among students, and the mobilization of the affective dimension, as seen in the spontaneous participation during discussions about the friendship network of the character “Pedro”, a theme that resonated emotionally with the children. The integration of cognitive, relational, emotional, and bodily dimensions fostered by educational psychodrama aligns with the concept of meaningful learning through experience and action, as proposed by Dewey (2022), and with the role of play in the construction of knowledge, as advocated by Vygotsky (1978). In this regard, studies such as those by Gibson (2012) and Bonani et al. (2021) highlight that playful, collaborative, and multisensory approaches enhance affective engagement and support the understanding of complex concepts by providing meaningful, embodied, and socially interactive learning experiences.

Regarding conceptual appropriation, the students demonstrated mastery of the basic elements of graph theory discussed during the intervention (e.g., node addition, adjacency verification) in both concrete and symbolic contexts. The accuracy observed in assessment tasks, combined with students’ responses during the intervention, suggests that these concepts were internalized through intuitive, visually grounded understanding. Furthermore, the diversity of answers provided to question R5 reveals substantial conceptual progress in problem-solving with graphs. Even without the formal introduction of weighted graph concepts, students devised their symbolic solutions to represent different intensities of relationships, using available materials and adapting elements from the intervention. Within the framework of Computational Thinking, this process reflects the purposeful modeling of structures and abstraction (Wing and Stanzone, 2016). The ability to represent complex relationships using self-selected resources (such as strings, colors, and shapes) is consistent with literature advocating the use of games and playful activities to promote logical reasoning, as shown in the works of Costa et al. (2017) and Gibson (2012). However, while these studies focus primarily on logical or manipulative activities, the present work advances the field by integrating body, emotion, and cognition as central components of the learning process.

The sharing moment offered a valuable opportunity for children to express their emotions, articulate the challenges encountered, and demonstrate their emerging conceptual understanding. This capacity to integrate affective, cognitive, and experiential elements aligns with Henry Wallon’s theory (Van der Veer, 1996), which posits that human development arises from the interplay of emotional, mental, and motor domains. Moreover, the reflective dialogue developed during the intervention highlights the importance of inviting children to critically engage with their experiences and interact meaningfully with their environment, as emphasized by Vygotsky (1978). The students’ subsequent ability to associate diagrammatic images with the concept of graphs further attests to the efficacy of educational psychodrama interventions in cultivating meaningful, durable learning memories.

This intervention introduces an innovative methodological approach by integrating the physicality of the body with computational data structures, thereby broadening the ped-

agogical possibilities for teaching graph theory at the elementary level. Educational psychodrama shows promise for facilitating the instruction of more advanced graph concepts, such as directed graphs, weighted graphs, and search algorithms. By exploring symbolic representation and improvisation, this approach empowers students to actively construct algorithms while engaging with rules and constraints in a concrete, sensory, and collaborative manner.

Altogether, the multimodal evidence—observational, interview-based, and assessment-based—indicates that the psychodramatic intervention effectively promoted the three dimensions examined in the research question. In other words, the children demonstrated the ability to comprehend and apply the acquired knowledge in a contextualized and structured manner.

6.1 Study Limitations and Future Directions

Despite the promising results, this study presents limitations that indicate valuable directions for future research. Because we did not collect individual-or group-level data, we were unable to examine how variations in behavior or social interaction may have influenced conceptual understanding or trace specific pathways of conceptual development, such as how a student moved from assigning materials randomly to applying symbolic reasoning with intention.

We did not gather granular data concerning the teacher's behavior, pedagogical choices, or specific aspects of her mediation, making it impossible to determine the influence of these factors on the activity outcomes. This gap arose from several constraints: video recording was not permitted, and the high complexity and number of variables present during the classes. Attempting to monitor these multiple dimensions simultaneously with only a single observer would likely have reduced the accuracy and completeness.

A further limitation concerns the thematic scope of the embodied dramatization. While the post-assessment (Connectville) did introduce a non-social context, the core intervention relied exclusively on the friendship relation. Future work could significantly enrich transfer by introducing alternative relational scenarios (e.g., transport networks, tournament schedules, or digital links). Alternatively, teachers could be empowered to select the context (e.g., transportation instead of friendship) that best aligns with curricular goals and local relevance. These new perspectives would also provide an opportunity to deepen the exploration of advanced topics, such as Directed Graphs.

Furthermore, as discussed in Section 5.3, the dramatization phase raised ethical considerations related to social inclusion. These reflections informed the design of a more inclusive alternative for future implementations and illustrate the iterative nature of designbased educational research, in which observed dynamics guide refinements in subsequent cycles.

Nevertheless, these limitations suggest several relevant directions for future research to deepen the understanding of the intervention's contributions. Among these, a particularly revealing line of inquiry would investigate the quality of children's comprehension of the

empirical abstractions acquired. Such research should employ individualized data collection instruments (e.g., interviews and systematic observations per student) to analyze observable criteria for the mobilization of empirical abstraction, specifically the recognition of action-result relationships (prediction) and the presence of generalizations.

7. Threats to Validity

Despite implementing multiple strategies to strengthen the study's methodological robustness, we must acknowledge its threats. First, despite the use of systematic protocols and methodological triangulation, some degree of unintentional interpretative bias may be introduced by the observer's engagement with the intervention.

Second, the presence of an external observer may provoke irritation or excitement in some students, and may elicit a desire in teachers to impress that presence (Cohen et al., 2002). To mitigate this risk, the researcher maintained a discreet presence and established rapport with the teacher and students through regular classroom visits before data collection. This strategy was crucial in maintaining a natural classroom atmosphere during the interventions and in building a foundation of trust with the teacher. Nevertheless, the Hawthorne effect (Adair, 1984) may still have led a few students to behave in ways they believed were expected, particularly during moments of heightened engagement or participation.

Finally, the study's limited size (two fifth-grade classes in a single public school) limits the generalizability of the findings. Although the school context is described in detail to support transferability, we advise caution when applying these results to other educational settings with different sociocultural, curricular, or resource conditions. Furthermore, variability in teacher facilitation and classroom dynamics (e.g., differences in interpreting instructions or in how students engaged with one another) may have influenced learning outcomes in ways that we could not systematically document.

8. Conclusion

This study presented and analyzed a pedagogical intervention based on educational psychodrama that introduced fundamental graph concepts and operations (e.g., element removal, adjacency) to fifth-grade elementary students ($N = 41$). The intervention integrated body, emotion, and imagination, allowing students to experience these concepts in a concrete and interactive manner. The results indicate that the intervention not only engaged the students but also supported processes of decomposition, abstraction, pattern recognition, the generation of informal algorithms (description of possible paths), and the transformation of symbolic situations into formal graph structures, thus promoting meaningful learning.

Despite its promising results, this study presents limitations that open important avenues for future research. One such avenue involves a comparative analysis between psychodrama-based interventions and other traditional or active learning methodologies, focusing on potential differences in cognitive outcomes, student engagement, emotional and social dynamics, and the development of spontaneity and creativity. In addition, there is a need

for studies that systematically observe teachers to understand how their decisions influence the implementation of psychodramatic interventions, identify challenges in applying psychodramatic techniques, and, most importantly, inform the development of effective teacher training strategies.

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Disclosure statement

The authors state that they have no competing interests to disclose.

Ethical Considerations

This study was conducted in full compliance with the ethical guidelines and was approved by the Federal University of ABC Ethics Committee (Approval No. 76829023.9.0000.5594).

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