The Impact of Strategy-Based Teaching and Thinking Maps on Sixth Graders' Achievement

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Abstract

This research focused on how strategy-based teaching with thinking maps affects sixth graders' achievement in science, learning engagement, memory retention as well as from the aspect of educational psychology. The participants were students from an Arab community in northern Israel. A mixed-method design was used, incorporating both quantitative methods in the form of pre-test/post-test and qualitative methods such as interviews, observations, and student reflection journals. Results indicated that students who used thinking maps in their lessons, compared to those taught through traditional methods, showed statistically significant improvements in their science scores and memory retention. Students qualitatively demonstrated improved engagement, enhanced understanding of concepts, and developed structured organized thought. Teacher participants noted improvements in classroom coalitions and cooperation. It appears that thinking maps have the potential to improve science education by enhancing motivational cognitive structures, interaction, and dynamics in a classroom setting. With respect to interviews and reflections, the qualitative analysis led to a range of insights through the thematic approach which enhanced the understanding and the deeper insights of the quantitative results particularly about motivation and clarity of concepts.

Keywords: critical thinking, memory retention, science performance, student engagement, thinking maps

Type of the research: Research Article

1. Introduction

Analyzing thinking maps in middle school science classes is important, because such a strategy can assist students in coping with complex science subjects and their level of cognitive development (Hakim, 2018; Vidergor, 2018). Sixth grade is a critical developmental stage, and hands-on and visual instruction can significantly increase students' learning potential (Grosser, 2020; Kim & Park, 2016; Van Tonder et al., 2022). Graphic organizers in the form of maps help pupils relate and assess scientific concepts, which is essential for more advanced topics like the water cycle and ecosystems (Newman, 2017; Saleh, 2020). These tools support middle schoolers' learning levels, thus optimally fostering enhancement and adjustment of the information acquired.

Outside the regional context, there remains a persistent gap regarding how strategy-oriented visual instruments operate within linguistically and socio-culturally diverse learning environments. Despite the extensive work done in concept mapping, very little attention has been paid to the customization of these frameworks for marginalized groups such as ethnic minorities, second-language speakers, and students from under-resourced schools. More understanding is needed in regard to the role that culture and language play in mediating the effectiveness of such tools in science education. This study examines both achievement and engagement outcomes within the context of challenges experienced by comparable underrepresented student groups across the globe.

Though there is a considerable amount of literature regarding the use of visuals in education, there is a lack of empirical research exploring how culturally adapting teaching strategies, like thinking maps, can be implemented for students from marginalized or non-mainstream linguistic backgrounds. This study attempts to fill this gap by offering some theoretical concepts for practitioners in science education of Arab-speaking learners. While some prior studies reported improvements in the learning of science through the use of concept mapping tools (Mansoor et al., 2018; Al-Mastrihi, 2021), most of them looked only at the general population or mathematics. There is a gap with regard to their impact when applied to instruction in science teaching in multicultural or linguistically diverse settings, and that is the focus of this study.

However, many of the prior studies examining the use of thinking maps or concept mapping tools have notable limitations. A significant flaw is their tendency to focus on general populations in homogeneous, often well-resourced educational environments, without addressing the unique challenges of diverse linguistic or cultural contexts. Moreover, much of the existing research is either theoretical or anecdotal, lacking empirical validation through controlled comparisons in real classroom settings. Some studies also failed to integrate students' and teachers' perspectives, overlooking how tools like thinking maps are experienced and interpreted by actual users in diverse learning scenarios. What distinguishes the present study is its application in a bilingual, socio-culturally distinct setting — Arab sixth-grade students in northern Israel — using a mixed-methods approach that not only measures learning outcomes quantitatively but also explores qualitative insights such as engagement, motivation, and classroom dynamics. This dual lens offers a more comprehensive understanding of both the cognitive and contextual effectiveness of thinking maps in a marginalized student population.

I chose a quasi-experimental pre-test/post-test design since it captures the value of comparative analysis in authentic classroom contexts that do not permit random assignment. This approach retains sufficient methodological rigor while also being relevant to real-life educational settings.

Most existing research, either substantiated or in the form of broad generalization, has already pointed out the advantages of carrying out concept mapping in science education, has been conducted in comparatively simpler, well-equipped, monolingual, and resourced settings. This research contributes novel insights by investigating the role of thinking maps as a strategic and visual learning tool in a bilingual culturally distinct setting. In particular, it assesses the effectiveness of these maps among the Arab sixth-grade students from northern Israel— a pedagogical science literature's underserved demographic. This research helps fill the gap of using culturally responsive strategies by ethnically diverse learners, and show how such tools can be used to overcome equity gaps in educational outcomes, specifically science learning, for multiply marginalized and underserved communities.

1.1 Research Questions and Hypotheses

This study was guided by the following research questions:

1. What is the impact of using thinking maps on science achievement among sixth-grade students?
2. How do thinking maps affect students' retention of scientific knowledge over time?
3. Does gender moderate the effect of thinking maps on science achievement?

Accordingly, the hypotheses are:

1. H1: Students taught with thinking maps will outperform peers in science achievement.
2. H2: Students using thinking maps will show greater knowledge retention after a delay.
3. H3: Gender will moderate the degree of improvement in science achievement among students using thinking maps.

2. Literature Review

2.1 Theoretical Foundations of Concept Mapping and Cognitive Development in Science Education

Alabdulaziz and Alhammadi (2024) argue that "concept mapping is rooted in cognitive and constructivist theories," as it offers techniques for pupils to proficiently organize knowledge, in addition to linking new information to previously learned materials. Grosser (2020) and Saleh (2020) attribute this learning method to Piaget who emphasized its assistance in abstraction and Vygotsky who included it in his ZPD as a guided learning tool (Suradi et al., 2024; Van Tonder et al., 2022; Weber, 2017). Schumacher (2022) and Van Tonder et al. (2022) provide additional references by attributing Novak's meaningful learning theory to concept maps as efficient tools through which pupils can interconnect and retain scientific concepts. Concept maps foster retention of information as asserted in dual coding theory by Alabdulaziz and Alhammadi (2024) and Saleh (2020). Kim and Park (2016) and Newman (2017), on the other hand, argue that maps exacerbate cognitive load and thus allow students to focus on key concepts that matter.

2.2 Constructivist and Social Learning Theories in Science Pedagogy

The Constructivist learning theory posits that new knowledge is created during the learning process through real-world activities, which is very important in teaching science (Aayasrh, 2015; Adeboye, 2022). While Bandura's theory places more importance on seeing learning from a social context, Piaget saw it through the lens of what a student knows and wishes to learn. Vygotsky's Zone of Proximal Development (ZPD) adds that guided interaction also helps the learner understand what they are learning at a deeper level (Al-Hamdani & Al-Qaisi, 2024; Newman, 2017; Van Tonder et al., 2022). From Bandura's perspective, students learn from watching their peers, which places further stress on group work and science practicals (San Miguel, 2021; Terungwa et al., 2024). Both constructivists and social learning theorists advocate for problem-based learning where students question issues and find solutions through hands-on learning (Alabdulaziz & Alhammadi, 2024; Hammad, 2015). In this case, teachers abandon their primary duty of lecturing and instead take on a more active role in planning and promoting group work as well as discussion (Schumacher, 2022; Bennett, 2015). Social constructivism also encourages collaboration so that students can elaborate on one another's ideas when learning difficult topics in science (Grosser, 2020; San Miguel, 2021). In fact, these theories promote interaction, exploration, and real-life activities, which form the core of science learning (Alabdulaziz & Alhammadi, 2024; Newman, 2017).

To conclude, both constructivist and social learning theories agree that science learning is enhanced through active participation, including interaction to establish and organize previously learned concepts. Thinking maps are an application derived from these theories as they ease collaboration, reduce cognitive load, encourage discourse, and aid in developing concepts. However, some findings are not uniformly positive. Grosser (2020) noted that among students with low prior knowledge, visual mapping was unlikely to yield significantly improved outcomes. Kim and Park (2016) also warn that visual aids may be unfavorable for students who prefer text and logic to visuals and images. These conflicting findings highlight the need for flexible, adaptable frameworks for instructional design.

Based on constructivist and cognitive theories, this study regards thinking maps as educational aids that correspond with the developmental levels and cognitive preferences of learners. They can enhance understanding of science, especially for learners from low socioeconomic status or culturally different backgrounds, by providing organized visual outlines. These frameworks are constructed to support the rationale for this study's examination.

3. Methodology

3.1 Research Design

The present study focuses on the application of a mixed-methods approach in examining the impact of thinking maps on students' performance and memory retention in sciences. The quantitative analysis employs a pre-post experimental design, where student's science scores are assessed prior to and following the use of thinking maps. This design allows the investigation of the achievement gain of students who were taught with thinking maps (the experimental group) as opposed to students who were instructed with traditional teaching methods (the control group).

As a supplement to the quantitative methods, this study employs qualitative methods such as semi-structured interviews and classroom observation. Students and teachers are interviewed to gauge their perceptions and experiences of employing thinking maps in science. Video observation provides an opportunity to see how lessons are delivered using thinking maps and how students interact with the materials in class.

The combination of qualitative and quantitative information reveals more information on the impact of thinking maps on students' performance as well as their experiences in the learning environment. The pre and post tests provide a basis for measurable changes in achievement while the interviews and observations depict how thinking maps impact students and teachers in the classroom.

The teaching experiment was carried out over twelve weeks. In the experimental group, students were taught science with lessons structured around thinking maps for all levels of instruction. Each unit was prefaced by the initial mapping step (e.g., ecosystems, photosynthesis, water cycle), where students meticulously crafted maps under the teacher's supervision, followed by independent mapping to reinforce and demonstrate knowledge. Lessons were composed of cooperative learning, guided discussion s of the maps, and formative evaluation through student-submitted diagrams. In comparison, the control group was instructed with a textbook in a teacher-centered lecture format without visual mapping aids. Both groups received the same material, within the same timeline, from equally qualified teachers.

3.2 Sample and Data Collection

A sample size of 60 students (30 per group) was selected based on a priori power analysis using G*Power software. Assuming a medium effect size (d = 0.5), alpha of .05, and power of 0.80, the calculated minimum sample size was 54. Therefore, the sample size was deemed sufficient for detecting statistically meaningful differences between the groups.

The analysis comprises two groups of sixth-grade students, totaling 60 children: 30 in the experimental group that received instruction with thinking maps, and 30 in a control group that received regular teaching. The participants are from the Arab sector in the north of Israel. They are enrolled in public primary schools and are representative of the region in terms of gender, as they include a proportionate number of boys and girls.\ The respondents' ages range from 11 to 12 years, which is the appropriate age for sixth graders in this area.

Both groups were checked to make sure that none of the students had any special educational needs or disabilities. This filtering out of particular students was important so as to have a uniform and similar cognitive and developmental level amongst all participants, in this case maximizing focus on the thinking maps students within the normal academic range. Students from both groups demonstrate, on average, grade-appropriate academic achievement and do not get any additional educational opportunities outside the routine curriculum.

To accomplish this research, purposive sampling was used to select a representative sample from the target population. Therefore, two sixth-grade classes belonging to the same school district were selected—one was the experimental group, and the other the control group. This decision was made so that both groups could be adequately matched in terms of age, academic performance, and other demographic information and facilitate their observation and data collection within the same school. This school-based setting enables the researcher to use a sampling method that creates ease of access to participants that need to be interviewed to hone down the measurements considered for the controlled setting.

In order to minimize possible confounding factors, both groups were selected from the same district, exposed to similarly qualified teachers, and studied the same material in the relevant period. Instructional parallelism was maintained throughout the research period, with no supplementary tutoring or enrichment programs provided.

3.3 Instruments

The impact of implementing thinking maps on student achievement and retention in Science is assessed using a variety of data collection instruments including a quantitative pre-post achievement test, semi-structured interviews, and classroom observations. Each tool is uniquely designed to capture distinct facets of the learning experience, combining to provide a rich, mixed-methods answer to the research question.

3.4 Quantitative Pre-post Achievement Test

The primary quantitative tool includes a pre and post achievement test created to determine the intervention's effect on the students' science knowledge. The tests adopted for this study are comprised of multiple-choice and short-answer questions alongside open-ended problems that evaluate both recall and analysis and synthesis levels of thinking. The questions are aligned with the science curriculum for sixth grade focusing on ecosystems, photosynthesis, and the water cycle, which were taught during the intervention period.

This Compute test is constructed bearing in mind the principles of assessment literature which stress on content validity and reliability. Bloom's Taxonomy provided the framework to ensure that levels of questioning ranged from knowledge acquisition to knowledge application and analysis (Anderson & Krathwohl, 2001). To test the reliability of the test, a version of the test is first given out to another group of students were did CRONBACH's alpha to check internal consistency. The last draft of the test underwent restructuring based on the comments received and item analysis done on the pilot data for clarity, appropriateness of level of difficulty, and the aims of instruction.

The pre- and post-tests created by the research team followed the national sixth-grade science curriculum and were validated by two independent experts in science education. The tests were conducted in class under uniform conditions, which were proctored by the teachers. Sample multiple-choice question: "Which of the following examples are producers in an ecosystem?" Sample open-ended question: "Using scientifically accurate terminology, describe how the water cycle aids in the growth of plants."

In accordance with Creswell and Creswell's (2017) suggestions, the interview protocols were crafted and tested with a smaller sample of students for ease of understanding. Each interview was conducted separately in Arabic, with verbal permission to record for future translation and analysis. The observation checklist was created using existing literature (Miles, 1994) and concentrated specifically on student interactions, mapping, and overall participation in the lesson.

3.5 Semi-structured Interviews

The use of thinking maps in science: students' and teachers' interviews give qualitative information about their perspectives, experiences, and attitudes about thinking maps. The interviews were guided by Creswell and Creswell (2017) qualitative interview protocols, which ensured that participants had the liberty to articulate their views and emotions in detail by having open-ended questions. The student interviews also explored their perceptions regarding the challenges they faced while using thinking maps and how these challenges impacted their understanding and retention of scientific concepts. For example, respondents were asked: “What challenges did you face when using thinking maps?” or “How did thinking maps assist you in understanding the science material?”

3.6 Observations of the Classroom

Observations of the classroom capture live unfiltered information regarding usage of thinking maps by the teacher and the interaction of the students with the maps during the lesson. These observations were done by researchers using a partial structured observational approach based on Miles (1994) qualitative research approaches. This protocol contains an elaborate specification of the perceiving of the engagement, interaction, and the depth of student–teacher relations during activities involving the thinking maps.

3.7 Student Reflection Journals

To aid in analysing metacognitive processes and motivational dispositions, students incorporated additional reflective elements capturing self-system processes where qualitatively assessed learning took place Students from the control group were asked to write short journal entries every week on how they used thinking maps while studying, what problems they faced, and how useful they thought the maps were. This provided effective self-reported data with them thinking about their awareness regarding their cognition and use of thinking maps for learning. He adapted prompts from Zimmerman and Schunk’s (2011) Self-regulation of Learning model with an aim to promote self-reflection and self-evaluation.

3.8 Teacher Feedback Forms

In addition to the student data, teachers were also asked to complete feedback forms at the end of the intervention. With the forms, teachers presented their perceptions of the effectiveness of the thinking maps as teaching aids and their effects on students’ behaviors, levels of engagement, and understanding of science concepts. These questionnaires contained both closed questions (effectiveness and why they disengaged the student) and open- ended questions e.g. “What major changes in students’ interests or understanding, if any, did you observe during the intervention period?” Such questionnaires were triangulated with interview data to highlight common themes from teachers.

3.9 Analyzing of Data

Thinking maps’ implementation on student achievement and knowledge retention was measured through pre- and post-tests. Incorporating quantitative and qualitative methods is the comprehensive approach I took for data analysis on this study. Statistical methods evaluated the performance changes that occurred, thematic analysis was used to structure qualitative interview data, observation notes, reflection journals, and teacher feedback forms. The following sections outline the statistical techniques and software for data analysis, as well as the qualitative coding processes.

3.9.1 Quantitative Data Analysis

All quantitative analyses were conducted using SPSS version 28. The reason SPSS was selected was because of its advanced statistical features and the ease of data collection and analysis it offered with the pre-and post-tests.

Thematic analysis was conducted using Braun and Clarke's (2006) six-phase process: (1) getting acquainted with the data through transcribing and reading, (2) developing initial codes, (3) identifying possible themes, (4) refining themes, (5) elaborating on and categorizing themes, and (6) writing the report. For the coding of data and clustering of data into themes, NVivo was used, which added reliability and consistency to the qualitative analysis.

For all paired comparisons, the pre-and post-test scores for both groups (control and experimental) underwent a paired t-test analysis. With these tests, it was possible to check if there was an increase in the science achievement of each group after the intervention. The paired t-test, by which students’ performances were compared before and after the intervention, gave an indication of whether there was an association of learning gains with the use of thinking maps for the students in the experimental group.

3.9.2 Qualitative Data Analysis

The qualitative analysis was approached using thematic analysis. This commenced with open coding, where the researchers examined the qualitative data sources in their entirety to construct initial codes based on prominent ideas, phrases, and concepts that were already present. For instance, during this stage, themes concerning student engagement, perceived challenges, and thinking maps as benefits were identified.

3.9.3 Integration of Quantitative and Qualitative Data

Mixed-Methods Analysis: Following the distinct examination of quantitative and qualitative elements, a comprehensive synthesis was performed. The qualitative data showing positive themes regarding student engagement and self-perceived understanding were considered along with the quantitative data's high averages in post-test scores. For example, one theme that arose with the post-test performance increase was the positive self-reports describing the students and teacher's understanding of the material.

3.10 Summary of Analysis

The statistical approach took advantage of t-tests, ANOVA, and effect sizes to quantify shifts in student achievement, although the qualitative approach portrays the context in which thinking maps affected student engagement and learning. Overall, these analyses enabled the researchers to effectively assess the effects of thinking maps on science achievement and knowledge retention among sixth grade students, which is vital information to educators and other stakeholders.

These findings illustrate the importance of blending qualitative and quantitative methods in a single study. In this case the results were not only objective learning outcomes but also rich accounts of the students' and teachers' experiences of thinking maps. These results make certain that the impact of the initiative is validated and encompasses the classroom setting.

4. Results

4.1 Quantitative Findings

Hypothesis 1: Improvement in Science Achievement Scores

To test Hypothesis 1, a paired samples t-test was conducted to compare the pre-test and post-test scores within the experimental group. Additionally, an independent samples t-test was conducted to compare the post-test scores of the experimental and control groups.

Table 1. Paired Samples t-Test Results for Pre-Test and Post-Test Scores in the Experimental Group

Measurement	***M***	***SD***	***t***	***df***	***p***
Pre-Test	62.4	8.7			
Post-Test	78.3	9.1	8.97	29	<.001

The results of the paired samples t-test regarding the experimental group are reflected in Table 1. The mean score in the pre-test for the experimental group was 62.4 (SD = 8.7) and the mean score in the post-test was 78.3 (SD = 9.1). The improvement from pre-test to post-test for the experimental group was statistically significant, $t(29) = 8.97$, $p < .001$. The effect size (Cohen's d) for the experimental group's pre- to post-test gain was calculated as $d = 1.64$, indicating a large effect and strong practical significance.

This means that the students in the experimental group, who worked with thinking maps, were able to achieve significantly greater gains in their achievement scores in science. These findings imply that teaching science with thinking maps as aids of instruction in classroom lectures resulted to better understanding and performance of the students on the measured science topics. The gains from pre to post test scores in the experimental group confirms Hypothesis 1 that the use of thinking maps resulted to improved student performance in science.

Table 2. Independent Samples t-Test Results for Post-Test Scores Between Experimental and Control Groups

Group	***M***	***SD***	***t***	***df***	***p***
Experimental	78.3	9.1			
Control	65.2	10.4	4.89	58	<.001

The independent post-test comparison of both the experimental and control groups have been depicted in Table 2. The mean post-test score for the experimental group was 78.3 (SD = 9.1) while the control group's mean post-test score was 65.2 (SD = 10.4). In independent samples t-test analysis, it was found that the mean difference between the groups was considerable with t (58) = 4.89 and p < 0.001. The effect size (Cohen's d) for the difference between experimental and control post-test scores was d = 1.38, also representing a large effect.

In fact, these results substantiate the claim that the experimental group performed better than the control group in the post-test, thereby validating Hypothesis 1 with additional evidence. To summarize, the quantitative evidence overwhelmingly affirms the hypothesis for the first statement which in this case is that the achievement scores in science of students from `thinking maps' classroom were significantly higher as compared to those from other control classes. The within and between group performance confirms the hypothesis and shows the utility of thinking maps in teaching science.

Hypothesis 2: Knowledge Retention in Science

To test Hypothesis 2, a follow-up test was conducted four weeks after the post-test to assess knowledge retention in both groups. An independent samples t-test was used to compare the retention scores of the experimental and control groups.

Table 3. Independent Samples t-Test Results for Knowledge Retention Scores Between Experimental and Control Groups

Group	***M***	***SD***	***t***	***df***	***p***
Experimental	75.6	8.9			
Control	61.7	10.1	5.21	58	<.001

Table 3 summarizes the results of the independent samples t-test of the retention test that was administered four weeks after the intervention. The experimental group using thinking maps had a mean score of 75.6 (SD = 8.9) on the retention test, in contrast to the control group which had a mean score of 61.7 (SD = 10.1). The difference between the two groups was statistically significant, t(58) = 5.21, p < .001. The effect size (Cohen's d) for the difference in retention scores between the groups was d = 1.51, which is considered large, highlighting the meaningful impact of thinking maps on long-term knowledge retention.

Thus, the experimental group retained more knowledge than the control group. These results verify Hypothesis 2, which posits that the integration of thinking mapping within science teaching improves knowledge retention over time. The much higher retention scores of the experimental group indicate that thinking maps facilitate constructive learning which enables the learner to retain scientific concepts better than through ordinary instruction alone. The information presented may imply that thinking maps help understand information in the short term and help in preserving the concept long-term. For instructional design purposes, this suggests that the use of visual organizational aids such as thinking maps can enhance retention and lower the rate of forgetting information over time.

Hypothesis 3: The effect of thinking maps on science achievement scores will differ depending on gender, with male and female students showing varying levels of improvement from pre-test to post-test within the experimental group.

To test Hypothesis 3, a two-way mixed ANOVA was conducted. This statistical test was selected to analyze the interaction effect between the within-subjects factor (pre-test and post-test scores) and the between-subjects factor (gender) on science achievement scores within the experimental group.

Table 4. Two-Way Mixed ANOVA Results for Science Achievement Scores by Gender in the Experimental Group

Source	***SS***	***df***	***MS***	***F***	***p***	***η²***
Pre-Post	2358.24	1	2358.24	35.72	<.001	.56
Gender	204.13	1	204.13	2.59	.115	.09
Pre-Post × Gender	412.75	1	412.75	6.25	.017	0.18
Error	1925.62	28	68.77			

The interplay between test time (pre-test vs. post-test) and gender (male vs. female) in the experimental group's science achievement scores were analyzed using the two-way mixed ANOVA method (shown in Table 4).

Main Effect of Time (Pre-Post): There was a significant effect within a time frame, which can be confirmed with $F(1, 28) = 35.72$, $p < 001$, $\eta^2 = .56$. Meaning that, post-test results were better than pre-test scores in regard to science achievement irrespective of gender. This claim corroborates the previous studies, considering that the employment of thinking maps used within a lesson improved students' science achievement.

Main Effect of Gender: The main effect of gender is not statistically significant, $F(1, 28) = 2.59$, $p = .115$, $\eta^2 = .09$. This implies that, on average, male and female students were not different in achievement scores consolidated over both time points, suggesting that gender alone has little significance in overall science scores.

Interaction Effect (Pre-Post × Gender): The interaction effect of the pre- and post-tests on gender was also significant $F(1, 28) = 6.25$, $p = .017$, with an effect size of .18. This suggests that the degree of improvement made from the pre-test to the post-test differs across male and female students, as one of the genders likely benefitted to a greater extent from the incorporation of thinking maps in science instruction.

In addition, thinking maps enabled both male and female students to improve their science achievement scores, but the degree of improvement was not uniform across the two groups. The significant interaction effect adds new knowledge that at least one of the gender groups performed better with thinking maps than the other resulting in them achieving a higher average score in the post-test compared to the pre-test. This implies that there is a possibility that the cognitive strategies, or learning preferences that thinking maps evoke may differ between males and females.

The result suggests that for thinking maps to be truly effective, they have to be adapted in a way that best suits male and female learners. Considering this and given the effect size for the interaction $\eta^2 = .18$, the potential impact of thinking maps upon gender differences is moderate, thus suggesting that differences do exist in the response of male and female students' intervention learning outcomes. This certainly draws attention on the need to further explore the impact of educational innovations such as thinking maps, particularly from a gender perspective.

To conclude this hypothesis, the data does seem to provide support: both genders benefitted from the use of thinking maps, but one gender received a greater degree of benefit than the other. Further consideration could determine if modifying thinking maps would equalize their effectiveness for both genders.

4.2 Qualitative Findings

Theme 1: Enhanced Engagement and Motivation

As already pointed out, one major outcome that was evident was the increased engagement and motivation of the learners toward learning science. There seemed to be an increased participation in many aspects of the learning processes.

Subcategory 1.1: Active Participation in Science Lessons

Participating students showed interest to talk and work actively with the thinking maps prepared in advance. Teachers reported increased interest among the previously passive students.

Teacher Observation: "Typically quiet students started to participate rather frequently. They seemed to enjoy the group work of developing the maps and, the ideas they generated were quite impressive. It was clear that thinking maps aided the student's confidence in science discussion." (Classroom Observation, Week 5)

Student Quote: "I felt more excited about science because I could since the maps were so helpful. I really wanted to participate and explain my map because it aided in clarifying my explanation." (Interview, Student 9)

Subcategory 1.2: Increased Self-Directed Learning

Students stated that they were self-motivated to research and learn science topics because they could use the thinking maps as templates for independent studying outside of the classroom.

Student Reflection: "I started using maps at home for studying, especially before quizzes. It was like I could see a blender for all the ideas to mix together, and that is what I think made studying more fun." (Reflection Journal, Week 7)

Theme 2: Better Understanding of Knowledge and Knowing How to Organize It

Thinking maps enhanced learning by fostering better understanding of the concepts by helping students relate the different science concepts. This organization is helpful in the arrangement of highly complicated or abstract concepts.

Subcategory 2.1: Development of Understanding Scientific Processes

Children learned more easily the sequential processes like the water cyclic or photosynthesis through flow mapping steps into visual units in a scientific diagram.

Student Quote: “Previously, I had problems with the water cycle because I wasn’t able to recall all the stages in the correct sequence. However, with the flow map, I could see all the component processes sequences with ease.” (Interview, Student 4)

Teacher Observation: “The maps helped students to appreciate the overall workings of scientific processes. Different parts of the map could be pointed to and oral explanations given and this indicates more understanding than just knowing facts.” (Classroom Observation, Week 6)

Subcategory 2.2: Information Problem Solving

Thinking maps did help children in the classification and organization of any information which was quite important in the classification of the ecosystems, animals, and other taxonomic groups.

Excerpt from a Student Interview: “With the tree map, organizing the animals into categories was quite simple. I definitely found it easier to remember the groups I had formed and it assisted me when sitting for the test.” (Student 12)

Excerpt from a Teacher Class Report: “The tree map facilitated the teaching of the ecosystem units very well. Students understood how various organisms interacted and began to inquire more about the rationale of some organisms being put in particular groups.” (Classroom Observation, Week 8)

Theme 3: Heightened Levels of Critical Thinking and Problem Solving

Thinking maps enhances critical thinking as they motivate students to analyze and synthesize relationships among concepts rather than recalling information.

Subcategory 3.1: Greater Levels of Attention to Detail

The teachers claimed that students who used thinking maps had an easier time analyzing and comparing concepts, which in turn, made them think more actively.

Teacher Quote: “I remember students exploring more sophisticated questions such as ‘What is the difference between these two concepts?’ or ‘Why does this process happen in such a way?’ The maps made it easy for them to seek answers.” (Interview, Teacher 2)

Student Quote: “Using double-bubble maps to compare different ecosystems was fun to me because I understood that each one is distinctive and yet has some common features.” (Interview, Student 10)

Subcategory 3.2: Problem Solving And Decision Making

Students resorted to using thinking maps for problem solving for scientific experiments or group works that required systematic inquiry.

Student Reflection: “When we performed experiments, I used flow maps to outline procedures. That way, I could know the steps we needed to take and what could have gone wrong when the results were not what was expected.” (Reflection Journal, Week 9)

Theme 4: Difficulty and Their Alteration With Teaching Maps

Although thinking maps had merits, students and teachers revealed some difficulty at first, especially with comprehending the rationale behind different types of maps. Eventually, they became used to the measures.

Subcategory 4.1: Trouble During The First Phase of Selection and Usage of Maps: Choosing and Mapping Information Put One Step Behind

In the beginning, students faced challenges in selecting the appropriate maps as well as in structuring information within the maps.

Student Quote: “I had no clue which map to choose. At times, I included heaps of information and therefore, the map became muddled. But through the lessons, I figured out what works best for what topic.” (Interview, Student 8)

Teacher Observation: “The initial few lessons were particularly difficult. Students had to acquire knowledge about different map types and learn when to use each. They needed a lot of support initially, which was provided to them, however, after a few weeks, they seemed to settle.” (Classroom Observation, Week 4)

Subcategory 4.2 Shift towards Improvement of the Adjustment Efficiency Based on The Increase In Proficiency Noticed During The Adjustment Phase.

Both students and even teachers reported some improvement in student's proficiency that has allowed them to utilize and create thinking maps independently.

Student Quote: "I recall that after a few lessons, I could mock up the maps without much thought. It was as if I had already learned how to set up the information in a way that made sense." (Interview, Student 5)

Teacher Observation: "At the conclusion of the intervention, learners were independently using maps to study. They even began to teach each other how to use them. The initial work was challenging, but these obstacles helped the students gain a skill they could use outside of science." (Classroom Observation, Week 10)

Theme 5: Teacher Reports Regarding Classroom Practices Related To Student Participation and Engagement

The use of thinking maps was found to impact the classroom atmosphere positively by enhancing student engagement and interaction.

Subcategory 5.1: Collaboration and Assistance Among Students

Thinking maps increased the ability of the students to cooperate as the students were able to help each other and work towards a common goal.

Teacher Quote: "It was incredible to watch students cooperate with the maps. They would pose questions to one another, offer suggestions, and actually worked together. This type of collaboration wasn't as common before we introduced the maps." (Interview, Teacher 1)

Observation Note: In group work, students often used each other's maps for comparison and discussion. Once, a student provided a peer with an explanation of how they constructed their bubble map by describing the parts of an ecosystem. (Classroom Observations, Week 6)

Subcategory 5.2: Furthering Interactions Between Teachers and Students

Teachers have suggested that thinking maps enhanced the quality of interactions since they were able to use the thinking maps to frame the questions and measure students understanding of the student effectively.

Teacher Quote: "The illustrated works were very effective at checking students' understanding. For instance, I could look at their works and evaluate whether they understood the topic or needed more help, which assisted me in providing accurate feedback." (Interview, Teacher 3) Observation Note: Now and then, teachers would grab students' thinking maps and have students explain sections of the map and then use that information to give feedback. This provided greater instructional differentiation in a group setting. (Classroom Observation, Week 7) The qualitative findings indicate that thinking maps enhanced students' learning experiences in science in more than one way. These tools improved engagement, actively motivated students to participate, and helped them learn in a more organized and structured manner. As the students learned more scientific concepts, developed analytical and problem solving skills, and became more proficient at organizing, sifting through, and synthesizing complicated information, they felt more confident. There were challenges at the beginning, but students and teachers learned to set thinking maps over time and with practice, leading to improved proficiency and independent use.

Moreover, thinking maps facilitated teamwork so learners could help one another and the teachers would participate more productively. In general, the results prove that thinking maps had academic impact, but more intricately – they contributed to the overall classroom atmosphere in a way that made learning science more enjoyable and active.

The synthesis of qualitative and quantitative results illustrates a clear convergence between learners' self-generated perceptions and their academic results. The engagement and motivation, as reported by students and teachers as well, aligns with the notable improvements in testing and retention. For instance, students' reflections concerning the use of thinking maps to organize their ideas were supported by better scores on questions regarding the scientific process.

5. Discussion

This research aimed to assess the impacts of thinking maps on a sixth graders' achievement, retention, and engagement in science. Although there is reason to be optimistic, these conclusions must be made under consideration of some caveats. It is possible that some teachers' excitement or pre-existing knowledge of the concepts on visual aids affected the fidelity of implementation. In addition, the specific culture bound nature of the environment may further restrict transferability to other groups lacking the same resources or teacher preparation.

These findings suggest that thinking maps helped students understand sophisticated science concepts by providing an organized way to store information. This could explain the better results from students who used maps. Rather than relying on rote memorization, thinking maps appear to have provided students with a more holistic understanding of scientific concepts and processes. This supports San Miguel's (2021) observations that visual mapping assists in connection making because it simplifies knowledge organization. Students may have been able to use thinking maps to more effectively understand the relationships and categories of science topics, which, in turn, enhanced their performance.

The use of thinking maps appears to have motivated the students to think about what they were learning and to engage with the material actively. Such metacognitive processes are particularly important in science because a learner must grasp intricate details of a phenomenon. Alabdulaziz and Alhammadi (2021) found that similar results were obtained when students' concepts and disorganization was attended to because it did enhance students' awareness of their thinking. These tools enabled students to identify areas of confusion resulting in better overall performance. This idea might help explain why students allocated to the experimental group did better not only after the test, but also relative to the control group.

Some key similarities and differences can be noted when comparing the current findings with existing literature. This study, like Mansoor et al. (2018) and Al-Mastrihi (2021), supports the assertion that visual organizers improve understanding and overall academic performance. Unlike Grosser (2020), who reported little improvement for low-achieving students, this study found even moderate-performing students showed considerable improvement, which is attributed to the extensive teacher guidance and culturally relevant instruction provided—unlike in Grosser's work. Alongside Kim and Park's (2016) observation that visual mapping disadvantages linear learners, the rigid modeling and differentiated instruction in this study seemed to eliminate that issue for most students. All of these examples illustrate the different ways a context of implementation, scaffolding, and student familiarity with the tools can shape the outcomes.

Thinking maps might have made the entire system simpler by separating intricate topics into smaller, manageable units which partially explains the academic gains. As Terungwa et al. (2024) pointed out, mitigating cognitive load is crucial in heavy subjects such as science. Thinking maps offer a way for students to arrange information which visually reduces the cognitive effort needed to remember details, therefore, students could focus on higher order thinking. This may have made it more effortless for them to comprehend and retain more content which is possibly the reason why students utilizing thinking maps had significant gains.

With thinking maps, students are probably expected to think critically because they are tasked to classify, relate, and analyze scientific concepts instead of simply memorizing them. Because learning is no longer shallow or simple, active participation greatly improves the chances of retention for longer periods of time. According to San Miguel (2021), students are prone to forget information if they do not take part in higher order tasks such as mapping and analysis. It seems that with thinking maps, students are encouraged to make connections, which increases the chances of them remembering the concepts.

The stronger retention results might stem from the fact that thinking maps reduce cognitive load. Complex topics can be broken down into visual chunks, which reduces the strain on the working memory, allowing for more in-depth learning. According to Newman (2017), students are able to store more information for the long term and retrieve it effectively when cognitive load is minimized. Because thinking maps potentially reduce the mental effort it takes to understand complex ideas, it is reasonable to assume that students in the experimental group were able to retain more information for longer periods of time.

In contrast, Grosser (2020) argued that the use of visual aids attempted to enhance memorization were ineffective when students did not have direct interactions with the material. One possible explanation for the difference in the current study is that students here had to use active participation in the form of construction of the thinking maps which involves organizing ideas and building relationships with the ideas being studied. Constructing thinking maps may improve retention since students perform the active role of integrating the elements of the study instead of passively using the maps as references.

Although some researchers suggest that thinking maps enhance retention, Kim and Park (2016) argued that students who prefer text-based, linear learning styles might not benefit much from these visuals. In this case, however, students received consistent instructions on how to work with thinking maps, which probably made them more accessible, even for visual learners who had difficulties. This type of teaching could have reduced any possible disadvantages of using thinking maps, making them suitable for a wider range of learners.

Conversely, Grosser (2020) reported minimal differences between visual tools and gender suggesting that at least in this case, gender does not matter as much as teaching approaches. This variation might result from how thinking maps were taught and presented in this study. Here, more directed support provided at the outset may have facilitated both sexes to participate, but perhaps one sex was able to adapt more readily and subsequently use the tools without assistance. The reason as to why one sex had more improvement over time, could be one explanation of this variation in comfort and ease with the maps.

There remains the possibility that certain forms of thinking maps will foster systematic thinking that corresponds with certain learning styles typical of one sex more than the other – which could be the case in science and mathematics. Newman (2017) pointed out that boys and girls may exhibit different patterns of strengths in science with some having preference for tools that aid in process and data construction and visual analysis. For learning of science, thinking maps may have been more appropriate for the gender that is more spatially inclined, thus leading to a greater increase for that group.

The noteworthy interaction of gender differences and learning outcomes must be interpreted thoughtfully. Even if one gender seems to benefit more, it could also stem from socialization, norms pertaining to participation in the class, or even ease with group and visual aids. Vidergor (2018) and San Miguel (2021) propose that some learners might be instinctively predisposed to performing better in group learning situations. Research should consider adapting thinking maps for lower structural oversimplification to explore whether they could be introduced with dealt scaffolded aids to foster support without reinforcing gender stereotypes.

Bennett (2015) was able to show that interactive tools can assist students who find traditional venues less engaging, and so can this. In order to cross these barriers, students needed a tool that actively engages and allows them to connect with the science topics materially and visually. The increase in student motivation and engagement that comes with thinking maps refracts from making the learning process more practical and straightforward especially in science which at times can be rather abstract. Thinking maps might have provided students with the ability to coherently engage with the material, thereby allowing them to surpass some of these educational obstacles.

The maps help students manage information and organize their thoughts leading to independent learning. This corresponds to the findings from Alabdulaziz and Alhammadi (2021), who noted that students who are given active learning tools tend to become more self-directed. It is possible that thinking maps provided a concrete structure to facts that seemed more or less as islands, which in turn aided students in reviewing the material. It is also possible that this structure provided some relief from the intense feelings of being overwhelmed and promoted self-study.

Thinking maps seem to enable students to explore relationships between ideas rather than memorize them, which in turn enhances their critical thinking and problem-solving skills. Tools that foster relational thinking have greatly helped students develop their analytical skills (San Miguel, 2021), and it can be argued that using double-bubble thinking maps to compare and contrast ideas helps sharpen students' understanding, leading to deeper questions and an enhanced grasp of science concepts.

Teacher observation noted that thinking maps have changed students' interactions during lessons for the better. The maps appeared to do build a learning environment that encourages students to be more active in providing ideas, giving responses and even assisting one another, thus fostering collaboration in the classroom. This phenomenon closely correlates with Vidergor (2018), who indicated that visual aids that enhanced participatory experiences stimulated students' cooperation. In this case, thinking maps motivated students to engage in discussion, strengthen peer relationships, and fostered a greater sense of belonging to the community.

Considering the specific aspects of thinking maps, they made interaction between teachers and students easier, as teachers were able, through student maps, to assess understanding and identify mistakes in real-time. This method allowed teachers to understand learning difficulties at an early stage and preemptively provide necessary corrective measures, a concept supported by Al-Hamdani and Al-Qaisi (2024), who asserted that such visual devises aid in lesson planning. This feedback was likely meant to enhance the understanding achieved by students and foster relationships of trust between the learners and teachers for more productive education.

In a more applied context, the broad implementation of thinking maps entails ongoing teacher training and several layers of instructional support. Educators need to be familiar not only with the distinct types of maps but also with how to effectively apply them across different disciplines. Proper teaching methods need to be put in place, otherwise, students may misapply or fail to take full advantage of the provided resources. Consequently, professional development and curriculum integration should be regarded as core requirements for effective implementation.

This research fills a gap within the literature by providing thinking maps, or graphic organizers in Israeli Arab contexts, with empirical evidence in settings where they are not commonly applied. In addition, it extends the literature by illustrating that thinking maps also enhance science achievement and retention not only in mainstream contexts, but also in minority settings when there is appropriate cultural and linguistic adaptation. Also important is how the mixed-methods approach uncovers the role that thinking maps play in the cognitive results as well as the emotional engagement and collaboration, which has received minimal consideration in a prior predominantly quantitative work.

6. Conclusions

This study advances our understanding of the functioning of thinking maps in science classes in minority, under-resourced cultures and how they are implemented. It underscores that the benefits related to these visuals—previously documented in majority populations—also apply to marginalized populations when teaching methods are adapted to their context. More crucially, it demonstrates the positive impacts of thinking maps improvement of cognitive outcomes like achievement and retention, but also engagement, collaboration, and metacognition. The scope of these benefits argues compellingly for the use of maps in teaching science in a variety of educational contexts.

This research sought to determine the influence of thinking maps on achievement, retention, engagement, and critical thinking of sixth graders in science. Through mixed methods, pre and post-test results were scored and analyzed, revealing remarkable science and memory gains for the group that utilized thinking maps from interviews, observations and journals. The analyses discovered an increase in engagement, understanding, critical thinking, and adaptation challenges. The results imply that thinking maps positively impacted academic performance and transformed the classroom environment by fostering collaboration and active participation.

7. Recommendations

Educators may start implementing thinking maps in particular science units where processes or relationships are prominent, such as in photosynthesis, the water cycle, or ecosystems. Lessons should first concentrate on orienting learners to each type of map (for example, flow maps and tree maps) through guided practice and explicit instruction. Schools may devote time during staff development days for interdisciplinary collaboration around the design and creation of thinking maps in order to promote a systematic approach to instruction.

In addition, there is value in understanding how thinking maps function for students of different backgrounds and different educational or cultural levels. There can be certain regions and mainstream schools that utilize thinking maps with the expectation that this approach is equally effective for all students. This kind of research would help aid in determining if thinking maps provide benefits for all learners, and understanding what changes, if any, need to be applied to address certain context-specific learning needs.

In all sciences classes, teachers can apply thinking maps as outlines that would aid students in comprehension and retention of knowledge. If thinking maps can assist in achievement as well as memory retention, science should be no exception, making even difficult concepts more interesting. Teachers may experiment with introducing thinking maps purposely, beginning with particular topics or units.

As with any other techniques, thinking maps have associated expenses and logistical requirements pertaining to their implementation within an entire school district. These include, but are not limited to, the lack of professional development time, instructional planning time, or training materials which, as mentioned, can hinder the expansion of these thought processes. Thus, some policymakers should consider initiating strategies using thinking maps at a minimal level in education, specifically starting at the pilot stage with ample time for mentorship among the educators.

8. Limitations

This study was constrained by its relatively short duration of 12 weeks, which does not account for the potential long-term retention or transferability of skills pertaining to thinking maps. The sample was limited to two grade six classes in one specific Arab part of northern Israel, which affects population generalizability. The researcher's presence during the observation phase might have affected either the teacher's or students' behavior was affected (i.e., Hawthorne effect). Another drawback concerns the initial steep learning curve associated with the different types of thinking maps; while students did adapt over time, early disengagement likely diminished overall impact. Finally, participants, in this case the teachers, tended to deviate from the prescribed method in such a way that the results could be affected without direct attribution, an aspect not sufficiently controlled within the research design.

9. Ethics Statements

The study involving human participants was reviewed and approved by the Sakhnin Academic College for Teacher Education Ethics Committee. All participants, including students and teachers, provided their written informed consent to participate in this study. For student participants, parental consent was also obtained prior to data collection. The study adhered to ethical guidelines ensuring confidentiality, voluntary participation, and the right to withdraw at any stage.

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Authors' contributions

Prof. Muhamad Hugerat was responsible for study design and revising. Dr. Sare Asli was responsible for data collection. All authors read and approved the final manuscript. In this paragraph, also explain any special agreements concerning authorship, such as if authors contributed equally to the study.

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As the author of this work, I didn't use any AI tool in this article. I, as the author, take full responsibility for the content of our published work.

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