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The Effect of Formative Assessment Practices in Science Education on Students' Cognitive Strategies Skills

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Abstract

The aim of this study is to examine the effect of formative assessment practices on seventh-grade students' cognitive strategies skills in the Science course. The quantitative part of the study, which was designed according to the mixed research approach, was based on a quasi-experimental design with pretest-posttest experimental and control groups, and the qualitative part was based on a case study design. The study group of the experimental dimension consisted of 48 students studying in the 7th grade, while 9 students took part in the case study. In the quantitative dimension, data was collected with the Science and Technology Course Self-Regulated Learning Strategies Scale. In the qualitative dimension, data was collected through interviews. The ANCOVA test was used to analyze the quantitative data. The data collected through interviews were analyzed with descriptive analysis and categorical content analysis techniques. As a result of the study, it was determined that formative assessment practices were effective on students' cognitive strategies skills. In addition, it was determined that students partially used cognitive strategies skills in the pre-interviews, but there were improvements in the level of using these skills in the post-interview. Based on the results obtained from the study, various suggestions were made.

Keywords: Cognitive Strategies, Formative Assessment, Performance-Based (Alternative) Assessment, Science

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INTRODUCTION

Assessment, which constitute one of the most crucial components of the instructional process, have a significant impact on various cognitive and affective characteristics of students, including their levels of learning (Yip, 2007), academic success (Ainley & Patrick, 2006), achievement goal orientations (Buldur & Doğan, 2017), motivation (Sassenberg & Woltin, 2008), and metacognitive skills (Gedikli & Buldur, 2022; Pintrich, 1999). One such variable is self-regulation. Self-regulation refers to the degree to which individuals actively participate in their own learning processes in behavioral, motivational, and metacognitive terms. To ensure active participation, individuals should not only display certain behaviors but also integrate their motivation, metacognitive abilities, and emotions into the process (Zimmerman, 1989). Given that learning occurs through the observation of one's environment, the need for learners to regulate their learning processes in line with their personal needs has led to the emergence of the concept of self-regulated learning (Üredi & Üredi, 2005), which can be defined as the process through which individuals actively regulate their cognition, motivation, and behavior (Pintrich, 1999).

In order for individuals to engage in self-regulated learning, they need to employ specific self-regulated learning strategies. According to Pintrich (2000), individuals can regulate their cognition and control their learning processes through the use of cognitive strategies, metacognitive strategies, and resource management strategies, thus achieving self-regulated learning. The development of students' self-regulated learning skills requires the enhancement of these strategies. Moreover, well-developed motivational strategies are also a significant factor in acquiring self-regulated learning competencies (Zimmerman, 1990).

Self-regulated learning skills can be supported and fostered through a variety of instructional interventions that guide students in the use of learning strategies, research on which has provided evidence of the impact of self-regulated learning on student achievement and motivation (Panadero et al., 2018). In addition, studies have focused on the role of assessment practices in promoting self-regulated learning. In particular, formative assessment practices have been found to be effective in supporting students' self-regulated learning skills (Dignath & Büttner, 2008). Formative assessment practices support self-regulated learning by providing students with opportunities to monitor and regulate their own learning during the learning process. Therefore, a strong relationship exists between these two concepts. Effectively implemented formative assessment practices help students conceptualize what they are aiming to learn, how they will recognize when they have learned it, and how they can proceed in the next steps. These processes activate students' cognitive and motivational capacities, get them to focus on learning goals, and help them develop feedback strategies that support goal attainment (Panadero et al., 2018).

Cognitive Strategies and Formative Assessment

In line with the aforementioned relationship between formative assessment and cognitive strategies, various studies have been conducted. In one such study, Theodoropulos (2011) emphasized that feedback, an essential component of formative assessment, supports students' cognitive processes. Similarly, Bonner et al. (2021) examined the use of think-aloud protocols to investigate the fundamental processes related to performance in the formative assessment of scientific thinking, and the study highlighted the importance of the cognitive strategies used during the think-aloud process and emphasized their relevance to formative assessment. In another study, Arsal (2009) investigated the impact of journal writing on preservice science teachers' self-regulated learning strategies. The findings indicated that journaling did not have a significant effect on the use of cognitive strategies among the participants. In a study involving students preparing for university, Conley et al. (2009) concluded that the cognitive strategies necessary for college readiness can be developed through formative assessment practices. Similarly, Baas et al. (2015) explored the relationship between assessment for learning and students' cognitive and metacognitive strategies in primary education. Their results demonstrated that assessment for learning positively contributes to students' self-regulated learning, as well as to the development of both cognitive and metacognitive strategies. Another influential study by Butler and Winne (1995) highlighted the importance of both internal and external feedback in helping students construct knowledge. Their model of self-regulated learning revealed that the use of feedback, both intrinsic and extrinsic, in alignment with formative assessment is significantly associated with the application of cognitive and metacognitive strategies. In light of these findings from the literature, it can be concluded that there is a substantial relationship between formative assessment and cognitive strategies. Based on this background, the research problem of the present study is formulated as follows: *"What is the effect of formative assessment practices in science education on the cognitive strategy skills of 7th-grade students?"*

The research questions within the framework of this general problem are as follows:

- Is there a significant difference between experimental and control group students' cognitive learning strategies pre-test and post-test scores?
- What is the change in the cognitive strategies (rehearsal, elaboration, and organization) of the experimental group students during the experimental process?

Significance and Aim of the Study

As aforementioned, self-regulation refers to the degree to which individuals actively participate in their own learning processes from behavioral, motivational, and metacognitive perspectives. In order to achieve active participation, individuals should incorporate not only their behaviors but also their motivation, metacognitive abilities, and emotions into the learning process. Furthermore, learners also manage their learning in line with self-defined goals, conduct self-assessments, identify how to access necessary resources, and regulate their self-regulated learning strategies through planning. Accordingly, how individuals regulate their own learning and how these skills can be fostered have become important research topics (Zimmerman, 1990).

Recent studies have also focused on the role of assessment practices in the development of students' self-regulated learning skills (Dignath & Büttner, 2008). Thanks to its inherent characteristics, formative assessment has significant effects on self-regulated learning. As formative assessment provides students with feedback and opportunities to monitor their learning during the process, it is closely associated with the development of self-regulatory skills (Panadero et al., 2018). Thus, implementing formative assessment practices that support self-regulated learning has become an essential component of school-based education (Sanzo et al., 2015).

A review of the literature reveals a substantial number of studies examining the relationship between formative assessment and self-regulation (Adewoye, 2018; Beekman et al., 2016; Çakır et al., 2018; Granberg et al., 2021; Hawe & Dixon, 2017; Ismail et al., 2022; Jing Jing, 2017; Liao et al., 2024; Luo & Lim, 2024; Kıncal & Ozan, 2018; King, 2003; Lysaght, 2015; Miraki et al., 2016; Ozan, 2017; Salas-Bustos et al., 2025; Tay, 2015; Xiao & Yang, 2019; Van der Linden et al., 2023; Ziegler & Moeller, 2012). While some of these studies generally address self-regulated learning skills, others specifically focus on the impact of formative assessment on cognitive strategies.

There are limited studies in the literature on the relationship between formative assessment and cognitive strategies. In one of these studies, Theodoropulos (2011) used a literature review design in his study, which stated that feedback, one of the important stages of formative assessment, supports students' cognitive processes. In another study, Bonner et al. (2021) used an interview technique in their study, which indicated that cognitive strategies are related to formative assessment. Arsal (2009), on the other hand, experimentally examined the effect of daily use on preservice teachers' cognitive strategies. As another example, Conley et al. (2009) used a survey design in their study, in which they stated that the cognitive strategies required for university can be developed through formative assessment. Similarly, Baas et al. (2015) used a survey design and concluded that assessment for learning contributes positively to self-regulated learning and students' cognitive and metacognitive strategies.

When the relevant literature is considered, the lack of experimental studies addressing the relationship between formative assessment and cognitive strategies becomes evident, indicating a notable research gap. To this end, the current study was conducted at the 7th-grade level within the scope of the science course to investigate the effect of formative assessment practices on students' cognitive strategy skills. Distinctively, unlike previous research, this study employed multiple assessment techniques rather than a limited set, aligning with the nature of formative assessment. Moreover, to ensure the integration of the assessment and instruction processes, the implementation in the experimental group was systematically carried out through the Science, Assessment, Instruction and Learning Cycle (SAIL-C) developed by Keeley (2008).

METHOD

Research Design

In line with the nature of the research questions, this study adopted a mixed-methods approach, which generally refers to an approach in which the researcher integrates both quantitative and qualitative techniques or methodologies (Tashakkori & Teddlie, 1998). Since the development of self-regulated learning skills requires detailed monitoring, this study employed an embedded design (Creswell & Plano-Clark, 2011), in which qualitative and quantitative data were collected either concurrently or sequentially to address different research questions, and data sets were analyzed independently. The quantitative dimension of the study was based on a quasi-experimental design, while the qualitative dimension adopted a case study design.

Study Group

In the experimental dimension of this embedded design study, the study group consisted of seventh-grade students from two separate classes in a public middle school located in a provincial center. Two classes with similar characteristics were randomly assigned as experimental and control groups. The total study group included 48 students (n Experimental = 24, n Control = 24).

For the case study dimension, the participants consisted of 9 students selected from the experimental group using the maximum variation sampling method. Based on scores obtained from the Science and Technology Self-Regulated Learning Strategies Scale administered as a pretest, students were categorized into low, medium, and high performance groups (33% each). Additional information about these students was gathered from their science teacher. After meetings were held with the selected students regarding participation, 3 students from each group were selected, forming a case study group of 9 students.

Data Collection Tools

In the quantitative phase, the data were collected using the Science and Technology Self-Regulated Learning Strategies Scale developed by Ilgaz (2011) based on the science curriculum and accompanying textbooks and teacher guides. The validity and reliability of the scale were tested with 386 students from 6th, 7th, and 8th grades. Exploratory and confirmatory factor analyses were conducted for construct validity, and Cronbach's alpha coefficients were calculated for reliability. Additionally, item discrimination indices were analyzed. The internal consistency coefficients for the subdimensions were reported as .70 for Rehearsal Strategies, .79 for Organizational Strategies, .70 for Elaboration Strategies, and .88 for the overall scale. In this study, a 20-item version of the scale focusing on Cognitive Learning Strategies was administered.

To capture the students' perceptions regarding changes in their cognitive strategies, semi-structured interviews were conducted with 9 students before and after the intervention using the Pre-Interview Form and Post-Interview Form. These forms were developed based on relevant literature (Gedikli, 2018; Ozan, 2017; Ulutaş, 2016), existing interview examples, and expert review. To encourage more detailed responses, follow-up prompts were added to each question, resulting in a six-question interview protocol.

Data Collection Process

Prior to the main implementation, a four-week pilot study was conducted with a different class from the one selected for the experimental application. The piloting was done by the researchers and consisted of 16 class hours during which the instructional materials (e.g., worksheets) intended for the main intervention were used. During the initial weeks of the piloting phase, some students were observed to have a difficulty adapting to certain techniques and formats in the worksheets, as they encountered them for the first time. However, with guidance, students gradually became more competent in managing their learning processes and successfully completed the worksheets.

The piloting also enabled the researchers to gain experience and develop solutions for potential challenges prior to the actual implementation. The main 14-week intervention included one week each for pre- and post-intervention data collection. The remaining 12 weeks were devoted to implementing the experimental procedures, which were carried out by the researcher. The weekly distribution of activities throughout the intervention period is presented in Table 1.

Table 1. Summary of experimental procedures

Week	**Procedures**
Week 1	Administration of pre-test and pre-interviews
Weeks 2 – 13	Implementation of instructional activities in experimental and control groups
Week 14	Administration of post-test and post-interviews

As seen in Table 1, the study with the students in the experimental group began with the administration of pre-tests, the selection of students to be interviewed, and the conduction of pre-interviews with those students. The instructional activities in the experimental group were implemented over a 12-week period in accordance with the Science, Assessment, Instruction, and Learning Cycle (SAIL-C) (Keeley, 2008). The lessons in the experimental group were conducted by the researcher. The techniques used during the experimental process and the topics to which these techniques were applied are presented in Table 2.

Table 2. Information on the techniques used during the experimental process

No	Name of the Technique	Topic Applied	No	Name of the Technique	Topic Applied
1	Friendly Talk Probes	Mitosis – Work	24	Comment Card	Work
2	Chain Notes	Mitosis	25	Sticky Bars	Work
3	Paint the Picture	Mitosis	26	Give Me Five	Work
4	Question Generating	Mitosis	27	P-E-O Probes (Predict-Explain-Observe)	Energy
5	Refutations	Mitosis / Particulate Nature of Matter	28	Informal Student Interviews	Energy
6	Structured Grid	Mitosis	29	No-Hands Questioning	Energy
7	Diagnostic Branched Tree	Mitosis	30	Data Match	Energy
8	Concept Cartoons	Meiosis / Energy	31	Odd One Out	Energy
9	Juicy Questions	Meiosis / Energy Transformations	32	Muddiest Point	Energy
10	Annotated Student Drawings	Meiosis	33	Analogy	Energy Transformations
11	Volleyball-Not Ping-Pong!	Meiosis / Particulate Nature of Matter	34	Performance Task	Energy Transformations / Particulate Matter
12	Fishbowl Think Aloud	Meiosis	35	Think-Pair-Share	Energy Transformations
13	Justified True or False Statements	Meiosis	36	I Think-We Think	Energy Transformations
14	Frayer Model	Meiosis	37	Concept Map	Energy Transformations
15	First Word–Last Word	Mass and Weight / Particulate Nature of Matter	38	Look Back	Energy Transformations
16	Focused Listing	Mass and Weight / Energy	39	Sequencing	Particulate Nature of Matter
17	RERUN	Mass and Weight	40	Two Stars and a Wish	Particulate Nature of Matter
18	Traffic Light Cards	Mass and Weight	41	Ten-Two	Particulate Nature of Matter
19	Poster	Mass and Weight	42	POMS-Point of Most Significance	Particulate Nature of Matter
20	Puzzle	Mass and Weight	43	Portfolio	Throughout the Experimental Process
21	K-W-L Variations	Work	44	Journal	Throughout the Experimental Process
22	Prefacing Explanations	Work	45	Self-Assessment	Throughout the Experimental Process
23	Fist to Five	Work	46	Peer Assessment	Throughout the Experimental Process

In the control group, instruction followed the standard curriculum using textbook-based activities. Like the experimental group, students were placed into heterogeneous groups. However, the experimental worksheets were not used, and traditional assessment methods such as multiple-choice tests, true-false, and fill-in-the-blank items were utilized for evaluating student performance. All instructional and assessment activities in the control group were also conducted by the researchers.

Data Analysis

Quantitative data were analyzed using ANCOVA via PASW 18 software. ANCOVA was selected due to its ability to control the influence of uncontrolled variables and to reduce within-group error variances, making it more robust compared to other analysis methods in experimental designs (Field, 2009; Kalaycı, 2010).

Qualitative data were analyzed using categorical content analysis, which involves breaking down the data into meaningful units and categorizing them according to pre-established criteria (Bilgin, 2006). Interview recordings were transcribed and coded by the researchers, who then identified categories and subcategories, calculated their frequencies, and validated the results through expert review. Direct quotations were frequently included to enhance reliability and present findings more vividly.

Validity and Reliablity

The reliability of a scientific study pertains to the consistency, replicability, and accuracy of data collection and recording procedures (Merriam, 1998). Validity refers to the precision and correctness of the findings, which can be categorized into two. Firstly, internal validity concerns whether changes in the dependent variable can be attributed to the independent variable, while secondly, external validity refers to the generalizability of the findings (Büyüköztürk et al., 2016).

There are many factors that can reduce internal validity in experimental research. These factors include time, subject characteristics, maturation, subject loss, data collection tools, pre-experimental measurements, and the influence of subjects' expectations (Fraenkel & Wallen, 2009).

To enhance internal validity, the study included a control group, used the same data collection instruments for both groups, and ensured an adequate number of participants after attrition. Random assignment was used to prevent selection bias and control for maturation effects. Participants were not informed about the experimental conditions to minimize expectancy effects. The worksheets and assessment tools used were reviewed and refined based on expert feedback.

As for the case study, efforts were made to increase trustworthiness by ensuring objectivity in data analysis, conducting analyses collaboratively, consulting experts, providing detailed descriptions of procedures, and supporting findings with direct quotations. Validity was enhanced by maintaining neutrality, involving experts in the process, conducting in-person interviews, and selecting participants relevant to the study objectives (Creswell, 2012).

Findings

In the study, quantitative data were collected using the Self-Regulated Learning Strategies Scale to determine the characteristics of students’ Cognitive Strategies Skills. The scale was administered as both a pre-test and a post-test. To examine whether there was a statistically significant difference between the pre-test and post-test mean scores of the participants in the experimental and control groups, the ANCOVA (Analysis of Covariance) test was utilized.

Findings and Interpretation Regarding the Quantitative Dimension

To determine whether there was a statistically significant difference between the pre-test and post-test mean scores of students in terms of the cognitive strategies factor, an ANCOVA test was planned. Prior to conducting the ANCOVA, its assumptions, normality, homogeneity of regression slopes, and homogeneity of group variances, were tested. As all assumptions were met, it was deemed appropriate to use ANCOVA to test the significance of the differences between the post-test scores adjusted for pre-test scores of students in the experimental and control groups. The descriptive statistics of the groups for the cognitive strategies factor are presented in Table 3.

Table 3. Descriptive statistics for pre-test, post-test, and post-test scores adjusted for pre-test

Group	n	Pre-test		Post-test		
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$*
Experimental	24	3.51	0.57	3.80	0.76	3.86
Control	24	3.67	0.60	3.58	0.66	3.52

*: Adjusted post-test mean based on pre-test scores.

As seen in Table 4, an ANCOVA test was conducted to determine whether there was a statistically significant difference between the groups in the post-test mean scores adjusted for the pre-test.

Table 4. ANCOVA results for post-test scores adjusted for pre-test

Source of Variance	Sum of Squares	*df*	Mean Square	*F*	Significance Level
Pre-test	8.842	1	8.842	27.872	0.000
Group	1.300	1	1.300	4.099	0.049
Error	14.275	45	0.317		
Total	677.105	48			

According to the results of the ANCOVA test, a statistically significant difference was found between the students in the experimental and control groups in terms of the post-test scores adjusted for pre-test scores [$F(1,45)= 4.099$, $p < .05$]. When examining the adjusted post-test mean scores, it is evident that the students in the experimental group outperformed those in the control group, which suggests that formative assessment practices had a positive effect on students' cognitive strategy skills.

Findings and Interpretation of the Qualitative Dimension

This section presents the findings and interpretations of the pre- and post-interviews conducted with nine students participating in the case study component. Based on the data obtained from these interviews before and after the intervention, students' progress in the dimensions of cognitive strategies (rehearsal, elaboration, and organization) was examined.

Findings and Interpretation Related to Rehearsal Strategies in Pre- and Post-Interviews

Figure 1 presents a model illustrating the categories and subcategories related to students' rehearsal strategies during the pre-interviews.

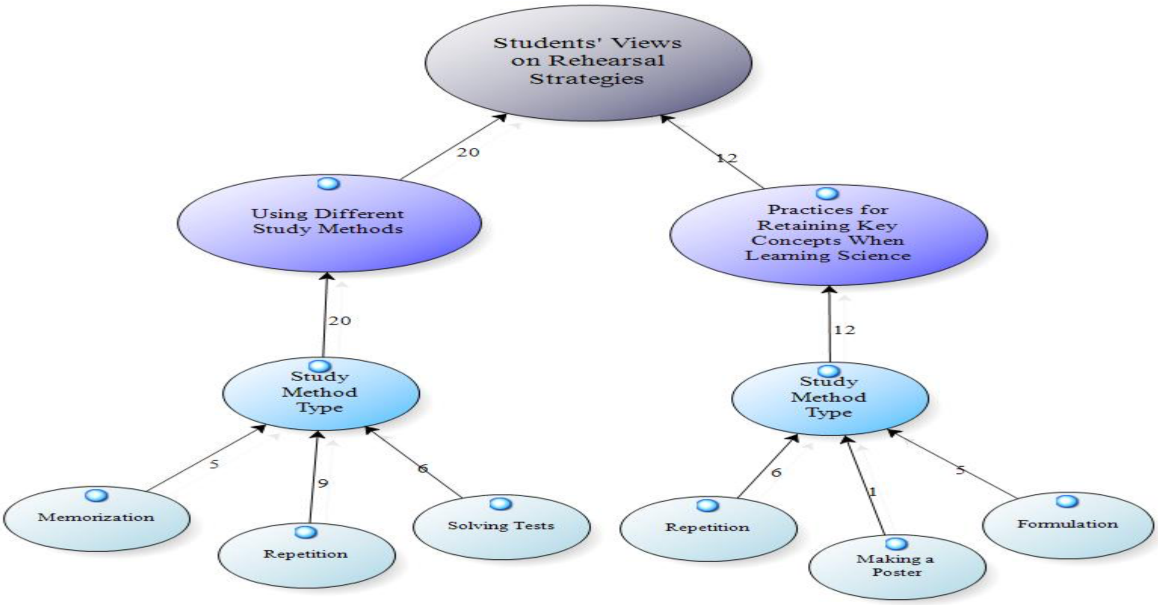

Figure 1. Model representing the categories and subcategories related to students' rehearsal strategies in the pre-interviews

Figure 1 presents, in the first category, students' views regarding the use of different study methods while studying for the science course. All students stated that they used various methods when studying for science. All of them mentioned having repeatedly read the topics; six students (S1, S2, S3, S7, S8, S9) stated that they solved practice tests, and five participants (S1, S2, S4, S7, S8) reported the use of memorization techniques. Some examples of student responses are provided below:

> *"While studying for the science course, I first solve practice tests. When I realize I cannot solve them, I study the topic and explain it to my mother, then I solve the test again. I use memorization while studying and read the topics over and over, because otherwise I can't remember them." (S1)*

> *"I do repetition, solve tests, and then study other subjects. I use memorization techniques while studying science. I memorize all the topics. I read the science topics repeatedly." (S7)*

The second category in Figure 1 includes students' practices for retaining key concepts when learning science. All students highlighted the efforts they made to remember important concepts. Six students (S2, S3, S4, S6, S7, S9) reported having repeated the topics, five students (S2, S3, S4, S5, S8) stated that they created formulas to retain key concepts, and one participant (S1) mentioned having created posters. Those who created formulas explained that they preferred this method because they found memorization difficult. Some examples of student responses are presented below:

“To remember key concepts, I create codes. For example, our teacher gave us a mnemonic about the planets, and I try to remember the topic using that. It also helps in the exam.” (S5)

“To keep it in mind, I repeat every day and create formulas from what I learn. For example, today I made codes from what we learned: The universe went into space, saw a galaxy, the hunter lost his arm, and entered the Earth.” (S3)

Figure 2 shows the model presenting the categories and subcategories related to students’ rehearsal strategies based on the post-interviews.

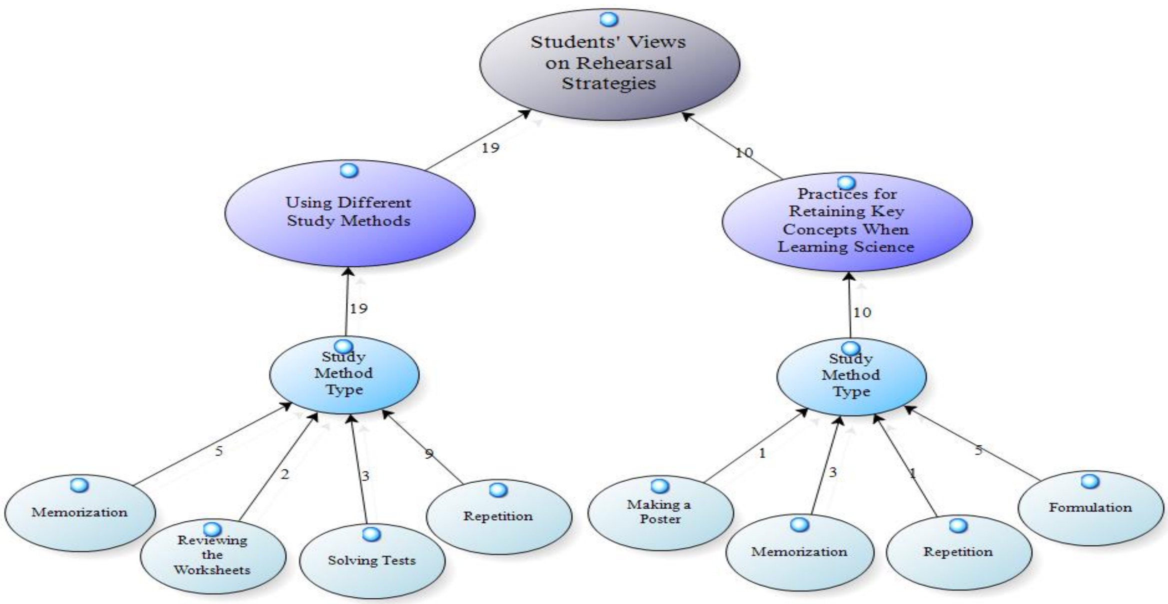

Figure 2. Model representing the categories and subcategories related to students’ rehearsal strategies in the post-interviews

Figure 2 presents, in its first category, students’ views regarding the use of different study methods while studying for the science course. All students reported the use of various methods while studying science. All of them mentioned having repeatedly reading the topics; five participants (S1, S2, S5, S7, S8) indicated using memorization techniques, three (S2, S5, S7) mentioned solving tests, and two students (S1, S8) noted reviewing the worksheets used in group work. Selected excerpts from students’ statements are provided below:

"While studying for the science course, I revise and solve questions. I use memorization, but it’s not very effective for me because I tend to forget. I read the topics repeatedly." (S5)

"While studying for the science course, I first revise the topics and then solve practice questions. I take notes on what I've learned. If there are parts I didn't understand, I study them again." (S7)

The second category in Figure 2 concerns practices aimed at retaining key concepts while learning science. Seven students (S1, S2, S3, S4, S5, S7, S8) stated that they made efforts to remember key concepts, while two participants (S6, S9) indicated that they did not engage in any such practices. Five students (S2, S3, S5, S7, S8) reported using formula creation as a memory aid; three (S2, S4, S8) used memorization; one participant (S1) created a poster; and another (S3) stated that they revised the topics. Those who created formulas noted that they preferred this method due to difficulties with rote memorization and because it helped the concepts stick better in their minds. Below are selected responses from students:

"While learning science, I don't use any formulas to remember key concepts. I mostly try to memorize." (S4)

"While learning science, I memorize and create codes. For instance, I form meaningful or meaningless codes by taking the initials of the words I've learned." (S8)

An analysis of the findings regarding changes in participants' cognitive strategies within the science course taught through formative assessment practices revealed that for the rehearsal strategies dimension, both interviews identified the categories of "using different study methods while studying science" and "engaging in practices to remember key concepts."

In both pre- and post-interviews, all students indicated using various study methods for the science course. In the post-interview, it was noted that some students utilized the activities on the worksheets employed during the experimental process. This can be interpreted as evidence that the experimental procedure positively contributed to the development of students' rehearsal strategy use.

In terms of the second category of rehearsal strategies, engaging in practices to retain key concepts, while all students in the pre-interview stated that they made such efforts, only seven students mentioned doing so in the post-interview. Compared to the pre-interview, variations were observed in the types of practices used. Additionally, in the pre-interview, students noted using formulas provided by their teacher. However, in the post-interview, they stated that they created their own formulas to remember key concepts. Since the activities in the worksheets involved both individual and group work, this shift suggests that the experimental process contributed positively to students' rehearsal strategy development.

Findings and Interpretation Regarding Elaboration Strategies – Pre- and Post-Interviews

Figure 3 presents the model displaying the categories and subcategories related to elaboration strategies based on the pre-interviews with students.

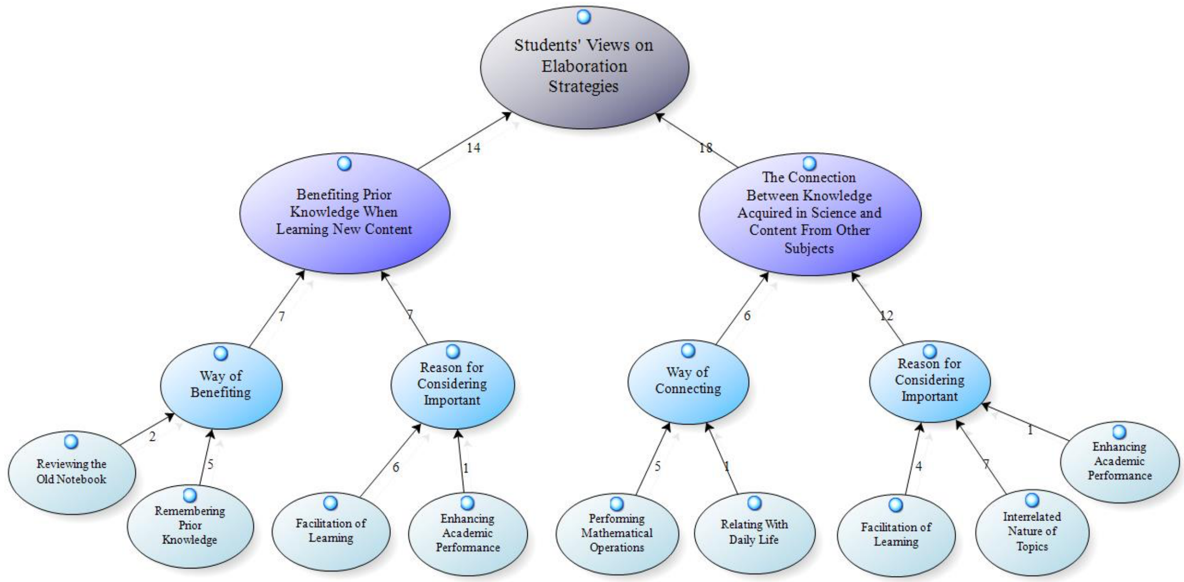

Figure 3. Model representing the categories and subcategories related to elaboration strategies based on students' pre-interviews.

In Figure 3, the first category presents students' views on utilizing prior knowledge when learning new content in science classes. Seven students (S1, S4, S5, S6, S7, S8, S9) reported that they benefited from prior knowledge while learning new content in science, while two participants (S2, S3) stated that they did not. Students who made use of prior knowledge indicated that it helped them learn topics more easily and that linking new content with existing knowledge made the new information more memorable. On the other hand, students who did not use prior knowledge acknowledged that it was important but admitted not applying this method themselves. Five students (S1, S4, S6, S8, S9) stated that they activated their prior knowledge through recall, while two participants (S5, S7) mentioned reviewing their old notebooks to access earlier content. All students emphasized the importance of utilizing prior knowledge. Six of them (S1, S4, S5, S7, S8, S9) highlighted its importance for facilitating learning, and one student (S6) noted its role in improving academic success. Selected student statements are presented below:

> *"It is important to benefit from prior knowledge. Most topics are connected to previous ones, and I also study past content. For example, I review my 6th-grade science notebook when I study." (S7)*

> *"I don't benefit from prior knowledge when learning something new. I think it is important, but I don't use it myself." (S2)*

The second category in Figure 3 addresses the connection between knowledge acquired in science and content from other subjects. Six students (S1, S2, S3, S4, S6, S8) stated that they made such connections, while three participants (S5, S7, S9) felt it was unnecessary. Students who linked science content with other subjects mostly reported associations with mathematics. Those who did not make such connections believed it was unnecessary or that other subjects were unrelated to science. Among those who established such interdisciplinary links, five students (S1, S2, S4, S6, S8) mentioned associations with mathematics, and one participant (S3) related science content to real-life examples. Furthermore, seven students (S1, S2, S3, S4, S5, S8, S9) emphasized the importance of these connections due to the interrelated nature of topics; four participants (S2, S3, S4, S5) highlighted the facilitation of learning, and one student (S8) pointed to increased academic performance as a result. Below are some illustrative comments:

> *"Connecting the knowledge I gain in science class with other subjects is important. For example, we can relate science to mathematics when dealing with topics such as speed. I also make such connections. Multiplication appears in both mathematics and science." (S2)*

> *"I relate science to other subjects. For example, science and math have a lot in common, and I make connections based on that. We do operations in both. Making such connections is important because I can apply what I've learned in one subject to another." (S4)*

Figure 4 presents the model that displays the categories and subcategories related to elaboration strategies based on the post-interviews with students.

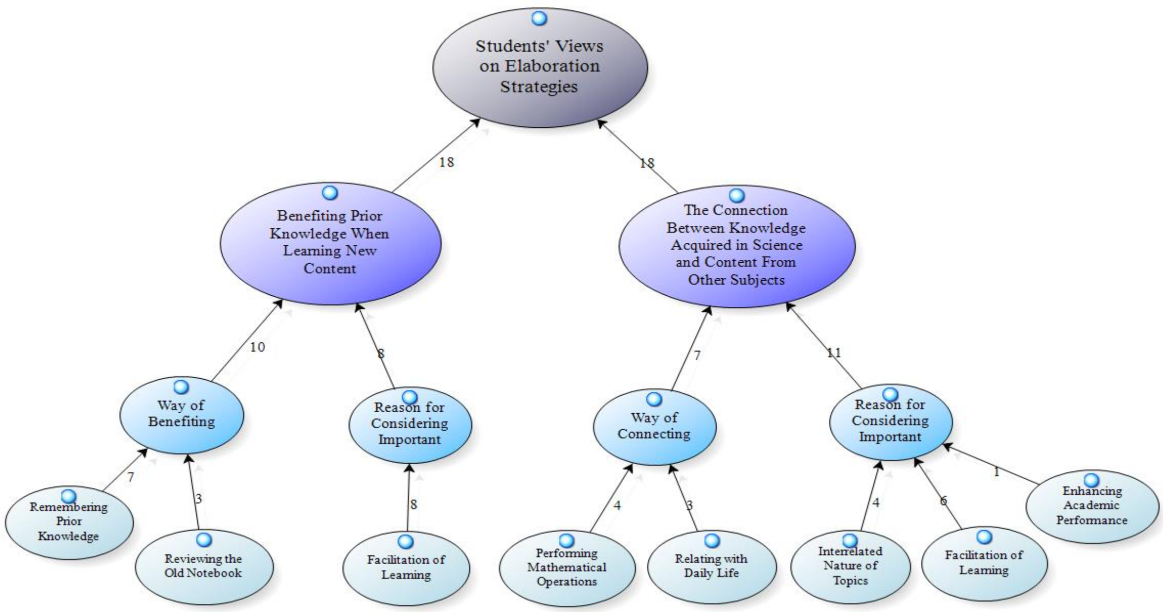

Figure 4. Model representing the categories and subcategories related to elaboration strategies based on students' post-interviews

In Figure 4, the first category presents students' views regarding the use of prior knowledge when learning new concepts in science lessons. Eight students (S1, S2, S3, S4, S5, S7, S8, S9) stated that they benefited from their prior knowledge when learning new information in science, whereas one participant (S6) indicated that they did not. Students who used prior knowledge emphasized that it helped them learn the topics more easily, made the new information more memorable, and facilitated understanding of previously unclear subjects. Seven students (S1, S2, S3, S4, S7, S8, S9) reported recalling previous knowledge as a strategy to learn new information, while three (S1, S3, S5) referred to their old notebooks. One student (S6) stated that they did not use prior knowledge when learning new content. Furthermore, eight students (S1, S3, S4, S5, S6, S7, S8, S9) emphasized the importance of using prior knowledge to facilitate learning, while one participant (S2) considered it unimportant. Selected student comments are provided below:

> *"When I use prior knowledge while learning something new in science, it stays in my mind better. It's important to use previous knowledge because the topics we study later will definitely be related to earlier ones. We often study similar topics. For example, last year we learned about the role of friction, and I used that knowledge when we moved to the new topic this year." (S8)*

> *"I think it's important to benefit from prior knowledge when learning something new. Even though we don't study the exact same topics as in previous years, they're related. So I use what I learned in the past to help understand new content. For instance, I had previously researched why Pluto was removed from the list of planets. This year, I looked into why it was reconsidered as a planet, and that helped me." (S3)*

The second category in Figure 4 focuses on students' ability to establish connections between science content and topics in other subjects. Six students (S1, S2, S3, S6, S8, S9) reported making such connections, while three (S4, S5, S7) did not feel it was necessary. Those who did make connections predominantly linked science with mathematics. Students who did not establish interdisciplinary connections stated that they found it unnecessary or that other subjects were not relevant to science. Among the students who formed connections, four (S1, S2, S8, S9) associated science topics with mathematics, while three (S1, S3, S6) related them to real-life examples. Additionally, seven students (S1, S2, S3, S4, S6, S8, S9) stated that establishing such links was important. Six students (S1, S2, S4, S6, S8, S9) said this was because it facilitated learning, four (S1, S2, S3, S8) because it highlighted topic interrelatedness, and one (S8) due to its impact on academic achievement. Some student statements are shared below:

> *"I think connecting science topics to other subjects is pointless. I don't make such connections." (S7)*

> *"I relate science topics to math topics. You could even say science equals math. The subjects are very similar. For example, calculations in mass and weight topics are related to math. Connecting science with other subjects is important. It helps you remember better and perform well in both. I connect science content with math topics." (S8)*

When examining findings related to students' cognitive strategies during the science course that incorporated formative assessment applications, two main categories were identified at both the pre- and post-interview stages under elaboration strategies: (1) Using prior knowledge while learning new content, and (2) Establishing connections between science and other subject areas.

In the pre-interview, seven students reported making use of prior knowledge, while in the post-interview, this number rose to eight. This suggests an increase in the number of students using prior knowledge after the intervention. Nearly all students reported utilizing recall to access prior knowledge and emphasized its role in facilitating learning rather than merely improving academic success. This may reflect the positive influence of the experimental process, particularly the use of group work and worksheets, on their elaboration strategy use.

For the second category, connecting science with other disciplines, six students in both pre- and post-interviews reported making such connections. Although the number remained the same, the increase in students referring to real-life examples during the post-interviews indicates that the worksheet activities implemented during the experimental process contributed to strengthening the application of elaboration strategies. Moreover, most students in the post-interview stated that making such connections is important primarily because it helps them learn more easily, further supporting the positive impact of group work and the use of formative worksheets.

Findings and Interpretation Regarding Pre- and Post-Interviews on Organization Strategies

Figure 5 presents the model displaying the categories and subcategories related to students' organizational strategies as revealed in the pre-interviews.

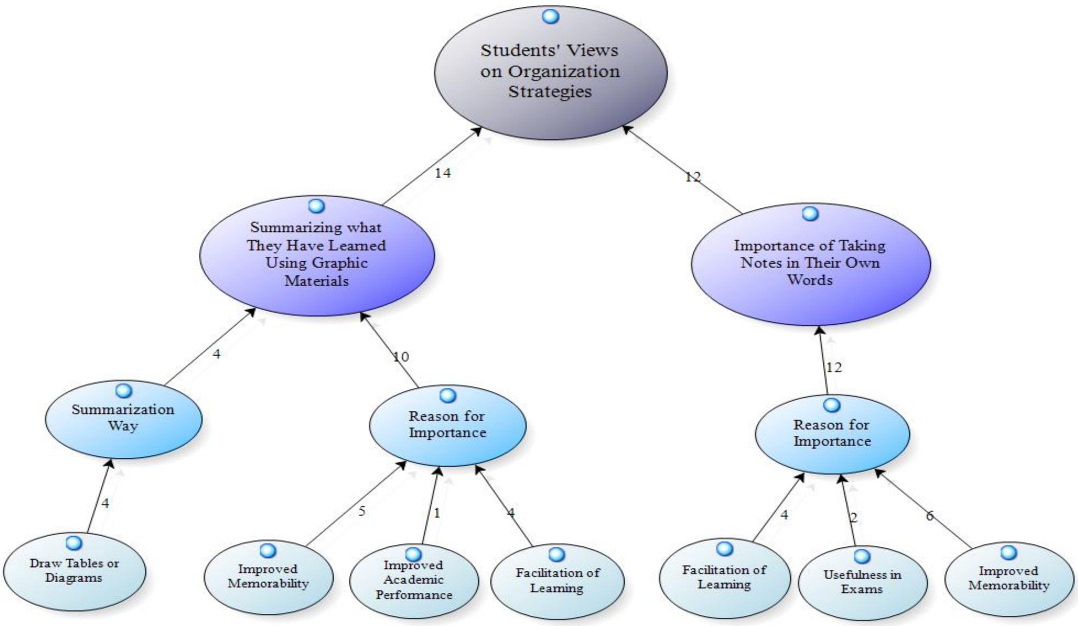

Figure 5. Model representing the categories and subcategories related to organization strategies based on students' pre-interviews.

In Figure 5, the first category presents students' views regarding their use of graphical materials to summarize what they have learned while studying for the science course. Four students (S1, S2, S5, S7) stated that they summarized their learning using graphical materials, while five participants (S3, S4, S6, S8, S9) reported that they did not. Students who used graphical materials indicated that it helped them learn topics more easily, improved their note-taking, and enhanced memorability by condensing long topics. Those who did not use graphical materials admitted the necessity of doing so, even though they personally did not apply the method. All students who used graphical materials reported drawing tables or diagrams. Moreover, all students emphasized the importance of summarizing their learning using graphical representations while studying science. Among these, five students (S3, S5, S6, S7, S9) stated it improved memorability; four (S1, S2, S4, S8) said it facilitated learning, and one (S1) indicated it improved academic achievement. Sample student statements are provided below:

"Using graphical materials while studying science is important. I do this as well. For example, I drew and tabulated what I learned about the moon phases in my notebook. I do this kind of work so that it sticks in my mind better." (S7)

"I don't use graphical materials when studying science; I don't prepare tables or anything. However, I think this way of studying is important. If we create a table, it stays in our minds longer, and we can refer back to it when we forget. I just don't study that way." (S6)

The second category in Figure 5 involves students' note-taking behaviors, specifically, whether they took notes in their own words while listening in science class. Seven students (S1, S2, S3, S5, S6, S7, S9) reported taking notes in their own words, while two participants (S4, S8) stated that they did not find it necessary. Students who took notes in their own words emphasized that it helped simplify long content delivered by the teacher and made studying for exams easier. Those who did not use this strategy believed it was unnecessary and that the teacher's dictated notes were sufficient. Additionally, eight students (S1, S2, S3, S4, S5, S6, S7, S9) acknowledged the importance of taking notes in their own words. Among these, six participants (S1, S2, S3, S4, S5, S9) stated it improved memorability; four (S2, S6, S7, S9) said it facilitated learning; and two (S4, S5) emphasized its usefulness for exam preparation. Some sample student responses are provided below:

"I don't think taking notes in my own words is important. I study based on whatever the teacher dictates." (S8)

"When I take notes in my own words, I learn more quickly and easily and don't forget. I do take notes in my own words. For example, I take personal notes about how genes are formed. Writing in my own words is important because it stays in my mind longer." (S2)

Figure 6 presents the categories and subcategories derived from students' post-interviews regarding organizational strategies.

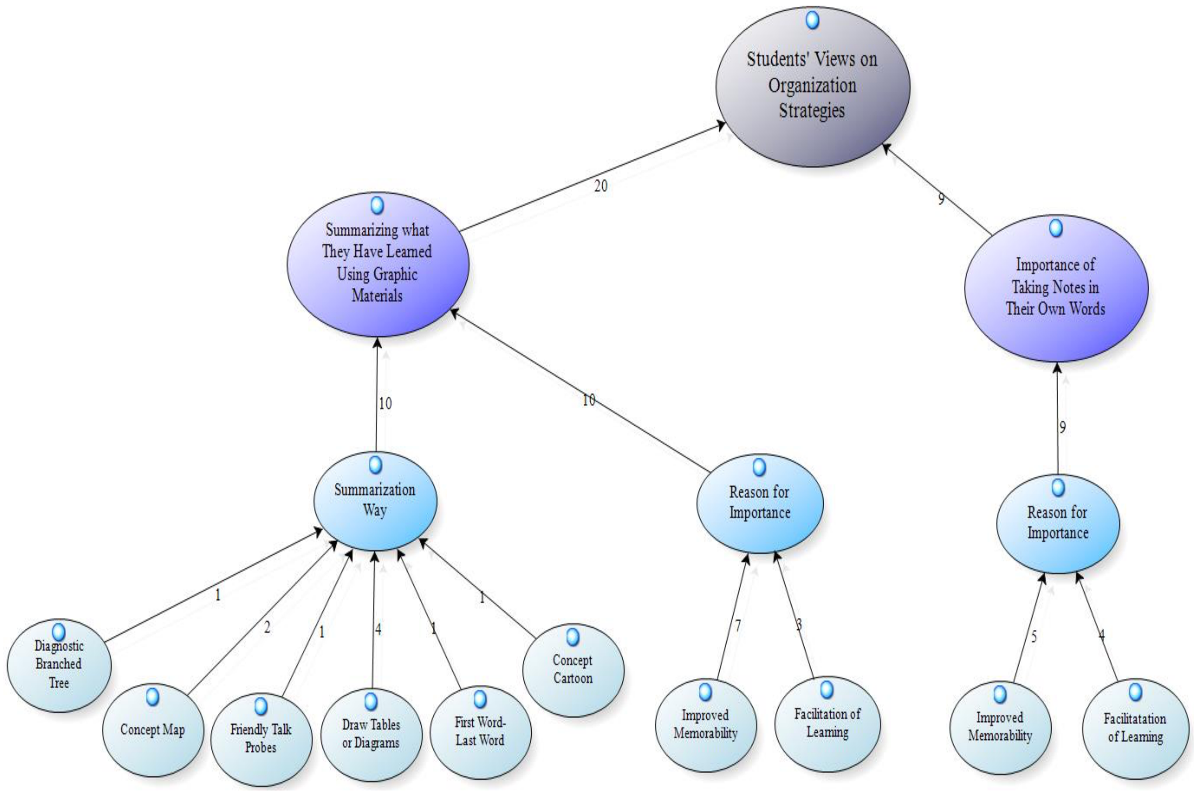

Figure 6. Model representing the categories and subcategories related to students' organizational strategies in the post-interviews

In Figure 6, the first category presents students' views on summarizing what they have learned in science class using graphical materials. Five students (S1, S2, S3, S6, S7) stated that they summarized their learning using graphical materials while studying, whereas four participants (S4, S5, S8, S9) reported not using this method. Those who utilized graphical summaries explained that this approach made it easier for them to learn concepts, improved retention through enhanced visuality, and allowed for more versatile use of knowledge. Students who did not use graphical materials admitted that such tools are beneficial, though they personally did not apply them.

Among those who used graphical materials, four students (S2, S3, S6, S7) indicated that they draw tables or diagrams; two (S1, S7) created concept maps; one (S1) used diagnostic branched trees; and one (S3) applied the techniques "Friendly Talk Probes?", "Concept Cartoon," and "First Word–Last Word." Additionally, seven students (S1, S2, S3, S4, S6, S7, S8) emphasized the importance of summarizing learning with graphical materials, citing improved memorability, and three of them (S1, S3, S6) also highlighted enhanced understanding. Sample student responses include:

> *"While studying for science, I take notes on Post-its and stick them to my board. I also draw tables and paste pictures onto cardboard. This way, what I learn stays more visible and memorable. Using graphical materials is important because just reviewing the content can be boring. These tools help me revise and understand the topic better. I really liked the group techniques like 'Friendly Talk Probes?', 'Concept Cartoon,' and 'First Word–Last Word.' I*

think these are effective both for making lessons more engaging and for deepening our understanding." (S3)

"I usually use concept maps to summarize what I've learned. I draw them on colored paper and hang them on my wall to help with memorization. I also prepare graphical materials myself at home. For example, I create diagnostic branched trees. Since I already know the answers, I can solve them quickly. Studying with visuals is very important. When I study from my notebook, it doesn't always stick. But when I prepare a concept map, all the details of the topic settle in my mind, and I can visualize the connections clearly." (S1)

The second category in Figure 6 involves students' practices of taking notes in their own words while listening in science class. Seven students (S1, S2, S3, S5, S6, S7, S8) stated that they took notes in their own words, while two participants (S4, S9) did not feel the need. Students who wrote in their own words explained that simplifying the teacher's lengthy explanations made the content easier to understand and more accessible for exam preparation. Those who didn't adopt this method felt that the teacher's dictated notes were sufficient.

Eight students (S1, S2, S3, S4, S5, S6, S7, S8) expressed the importance of note-taking in their own words. Five of these (S1, S2, S3, S4, S7) cited enhanced memorability, while four (S3, S5, S6, S8) emphasized improved comprehension. Sample statements include:

"I take notes in my own words while listening in science class. It's important because my own phrasing sticks better in my mind. The teacher's explanations are long, but when I shorten them, they become more memorable. Even a single word can help me recall things." (S7)

"I take notes in my own words. For instance, if the teacher writes a long sentence, I rephrase it in a way I understand. Writing long sentences makes my hand tired. So, to avoid fatigue and improve understanding, I write in my own words. It's important because I can't always memorize long sentences, they don't stay in my mind. Writing shorter, clearer sentences helps." (S3)

When examining the findings related to changes in students' cognitive strategies within the context of science lessons conducted with formative assessment practices, two consistent categories related to organizational strategies emerged in both pre- and post-interviews: (1) summarizing learning using graphical materials, and (2) taking notes in one's own words during instruction.

In the pre-interview, four students reported using graphical materials to summarize their learning, while this number increased to five in the post-interview. Initially, students only reported using tables and diagrams; however, after the intervention, they described applying additional techniques such as concept maps, diagnostic branched trees, "Friendly Talk Probes?", "Concept Cartoon," and "First Word–Last Word" found in the activity sheets. This change suggests that the experimental intervention contributed positively to students' ability to apply organizational strategies.

The increase in the number of students using graphical summaries, their emphasis on improved memorability rather than achievement, and the intention of non-users to adopt these techniques later are noteworthy indicators of progress

Regarding the second category, taking notes in one's own words, seven students expressed in both pre- and post-interviews that they adopted this strategy. In both sets of interviews, students emphasized the role of this practice in facilitating learning and enhancing memory retention. Following the implementation of performance-based (alternative) formative assessment techniques, students increasingly focused on the benefits of self-written notes and reported reduced exam anxiety, suggesting that the intervention supported the development of their organizational strategy skills.

DISCUSSION AND CONCLUSION

When the quantitative findings regarding students' cognitive strategies were examined, a statistically significant difference was identified between the post-test scores of participants in the experimental and control groups. These results indicate that the experimental process had a significant effect on students' cognitive strategy skills.

Similarly, the qualitative findings regarding students' cognitive strategies were consistent with the quantitative results. During the pre-interviews conducted with the experimental group before the intervention, it was observed that students made partial use of cognitive strategies, including rehearsal, elaboration, and organization. However, in the post-interviews, it was found that students showed notable improvements in their use of these strategies and reported more frequent usage. Evidence supporting this includes students' statements during the post-interviews, such as continuing to use the worksheets after class, forming conceptual formulations independently rather than with teacher assistance, using prior knowledge to acquire new information, emphasizing the importance of relating topics across subjects to facilitate learning, utilizing graphical materials in the worksheets for summarizing, and noting that taking notes in their own words made learning easier and reduced test anxiety. These findings collectively point to a positive development in students' ability to use cognitive strategies.

Previous studies have also highlighted significant relationships between different assessment practices and students' self-regulation skills (Ismail et al., 2022; Liao et al., 2024; Luo & Lim, 2024; Ozan, 2017; Salas-Bustos et al., 2025; Ziegler & Moeller, 2012), and more specifically, between formative assessment and cognitive strategy use (Arsal, 2009; Baas et al., 2015; Bonner et al., 2021; Butler & Winne, 1995; Conley et al., 2009; Theodoropulos, 2011). For instance, in a study by Arsal (2009), it was concluded that journal writing had no effect on preservice science teachers' cognitive strategies. The contrasting results between Arsal's study and the current one may be attributed to differences in the study samples. Moreover, unlike Arsal's study which focused solely on journal use, the present study incorporated multiple assessment techniques, employed a comprehensive instructional model, and involved a longer intervention period, factors which may explain the observed differences in outcomes.

In a study using a different design, Baas et al. (2015) found that assessment for learning contributed positively to students' self-regulated learning as well as their cognitive and metacognitive strategies. Similarly, Bonner et al. (2021) emphasized the importance of cognitive strategies used during think-aloud protocols and noted their connection to formative assessment. In another influential study, Butler and Winne (1995) highlighted the significance of both internal and external feedback in knowledge construction. Their model of self-regulated learning demonstrated how both types of feedback, when aligned with formative assessment practices, are associated with cognitive and metacognitive strategies. Likewise, Conley et al. (2009), in their study on college readiness, concluded that the cognitive strategies required for success in higher education could be developed through formative assessment practices. In parallel with the findings of these studies using various research designs, the present study also confirms that formative assessment practices have a positive impact on students' cognitive strategy skills.

Limitations

This study is specifically limited to investigating the impact of formative assessment practices on students' cognitive strategy skills within the context of the Science course. The participants of the study consisted of 48 seventh-grade students, and the data collection methods were limited to a scale and semi-structured interviews.

In the qualitative dimension of the study, it was initially planned to record the lessons via video in order to observe the changes and developments in students' learning processes more effectively. It was also anticipated that showing these recordings during the interviews could support students in recalling the learning situations they had difficulty remembering. However, due to the school administration's disapproval and students' concerns about being recorded, this implementation could not be carried out.

Recommendations

This study examined the effects of formative assessment practices on students' cognitive strategy skills within the scope of the Science course and found that formative assessment practices were effective in enhancing these skills. Based on this finding, it is recommended that formative assessment practices be integrated into classroom instruction in Science education to support the development of students' cognitive strategies. Although this study was conducted specifically within the Science course, the positive impact observed suggests that formative assessment practices could also contribute to the development of cognitive strategy skills in other subject areas. Therefore, to strengthen this claim, future studies could explore the use of formative assessment practices across different disciplines and with various sample groups. Additionally, in the quantitative dimension of the study, the Science and Technology Self-Regulated Learning Strategies Scale as used, while semi-structured interviews were conducted before and after the intervention in the qualitative dimension. Future research could benefit from using additional data collection methods, such as classroom observations, to enhance the validity of the findings. Given the limited number of national studies examining the relationship between students' cognitive strategy skills and assessment practices, it is recommended that more research be conducted in this area to enrich the literature and guide educational practice.

Declarations

Publication Information

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Author: Fatih UNAŞ

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The dataset used and analyzed during the current study is available upon reasonable request.

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Both authors contributed equally to the conception, design, data collection, analysis, and writing of the manuscript.

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The authors declare that there are no conflicts of interest regarding the preparation, implementation, data collection, interpretation of results, or writing of this research.

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All procedures performed in this study comply with the ethical standards outlined in the "Directive on Scientific Research and Publication Ethics of Higher Education Institutions." None of the acts defined under the section "Violations of Scientific Research and Publication Ethics" were committed.

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