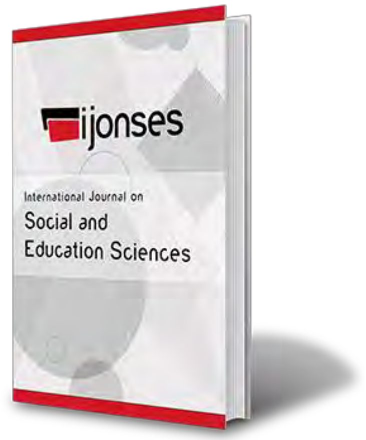

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The Effect of Brain-Based Learning on Students' Metacognitive Awareness

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Abstract

The purpose of this study is to examine effects of Brain-Based Learning (BBL) method on seventh grade students' metacognitive awareness. Concurrent nested mixed method was used in the study. Thirty 7th grade students (21 girls, nine boys) participated in this study voluntarily. The unit of "Structure and Properties of Matter" was taught using the BBL method for six weeks. Students' Notebooks, Strategy Evaluation Matrix and Regulatory Checklist, were used for qualitative data. Metacognition Scale was applied as a pre-posttest for quantitative data. According to the results, while there was no significant difference between the Metacognition Scale pre-test and post-test results, a significant difference was observed in Conditional Knowledge, which is the Knowledge of Cognition sub-dimension of the scale. The findings obtained from the Strategy Assessment Matrix show that the students use high-level strategies (Affective Strategy) and techniques (Attention Concentration), so the Brain-Based Learning approach increases students' metacognitive awareness. When the expressions in the Regulatory Checklist were examined, it was seen that as the process progressed, the awareness of the students increased and the strategies they used worked.

Introduction

Continuous change and transformation in information and technology affect many things, from how people process information to their way of working, from the communication they establish to their strategies to redeem the time. In order to keep up with this rapid and intense change that affects people's thoughts, perceptions and values, they should be able to develop different perspectives on thinking, learning and living and being aware of their potential (Anderson, Love & Tsai, 2014). This awareness can be explained by metacognition, which is a broad term that covers both knowledge and regulation of human cognitive activity (Fernandez-Duque, Baird & Posner, 2000).

Metacognition is the awareness and reflection of one's own cognitive process (Flavell, 1979). Although metacognition generally develops depending on age, many studies show that the effect of teaching on the acquisition of metacognitive skills have a positive impact on students' thinking skills (Stewart, Cooper & Moulding, 2007). In this respect, education is the factor that will provide people with the new skills they need by making them aware of their cognitive processes. The development of metacognitive skills and abilities also depends on supporting quality education (Nunaki et al., 2019).

In today's conditions, there is a crucial need for education that focuses on teaching what is the ability to know instead of directly transferring the ever-increasing and changing information (Palavan & Başar, 2014). Brain-Based Learning, one of the learning models that responds to this need, is a comprehensive teaching approach based on current neuroscience research on how the brain learns naturally (Kristanto & Pradana, 2021). Brain-Based Learning makes it possible to think about the learning process (Duman, 2010). It enables students to experience meaningful teaching based on their own experiences (Yandow, 2007). Which learning activities have a high effect on reaching these experiences can also be learned through knowing how the brain works (Ramakrishnan & Annakodi, 2013). A basic understanding of the anatomy and physiology of the brain is necessary to understand better the basis of the learning process and learning behaviors, and to understand how the brain learns. Because every task the brain completes requires communication and coordination between its various parts (Cercone, 2006).

Teaching strategies can be diversified in order to make Brain-Based Learning more effective (Yandow, 2007). At this point, one of the ways that can be used by educators is to apply Brain-Based Learning with metacognitive strategies. Integrating the Brain-Based Learning approach with metacognitive strategies provides advantages such as organizing the learning process in terms of active thinking. Thus, metacognition, a stimulus in thinking, can be provided to plan, understand, control, and evaluate the learning process in a unique way (Susilawati, Abdullah & Abdullah, 2020). Likewise, in science education, metacognition has a key role in deepening the conceptual understanding of scientific ideas (Avargil, Lavi & Dori, 2018). Awareness of the learning process and stronger ability to monitor, regulate, and control learning contribute to the learning of science subjects in a meaningful way and develop scientific research skills (Zion, Michalsky & Mevarech, 2005). Metacognition is the reciprocal function of the brain regions responsible for activities related to processing the material to be learned according to the objectives of a task. Ensuring the connection between the brain and metacognition may support learning (Shwartz, Scott & Holzberger, 2013

Brain-Based Learning

Over the years, many attempts have been made to understand how our brain works, and various models have been put forward. Today, brain theory focuses more on a holistic view of the brain. This theory emphasizes a more systems-based approach in which the whole is greater than the sum of its parts. In this context, neuroscientists conduct clinical research involving various groups of people to gather reliable information about how our brain works. A brief summary of these studies carried out is presented in the following (Springer & Deutsche, 1993).
In 1836, Mark Dax found that the right side of the body is activated by the left lobe of the brain, and the left side of the body is activated by the right lobe of the brain. For the first time, German anatomist Franz Gall suggested that the brain does not work as a whole and there are parts of the brain where different cognitive functions occur. In 1861, Paul Broca divided the brain into four parts: frontal lobe, parietal lobe, temporal lobe and occipital lobe. Paul Broca concluded that everything related to speech takes place strictly in the left lobe in 1864. John Hughlings Jackson proved that the right lobe also has functions in 1865. In 1930, Wilder Penfield and his associates at the Montreal Neurological Institution applied electrical stimulation to the brain in order to determine the exact locations of various functions occurring in the brain. It was found that the right lobe has visual superiority and the

left lobe has verbal superiority, by cutting the Corpus Collosum, which is the link between the two brain lobes while allows them to be adjacent and aware of each other by Jerre Levy and his colleagues in 1940. In 1960, Maclean said that the evolutionary development of the brain consists of three basic structures called the reptilian system, limbic system (emotional brain) and neocortex (logical brain). Geschwind and Levitsky investigated physical differences in the brain. In the 1990s, it was revealed that the abilities related to music in humans are in the right brain. In the 20th century, Juhn Wada applied the "Wada test for determining function locations" (Duman, 2010; Gocen, 2021).

These studies have been useful in determining how human learning occurs (Bonomo, 2017). Scientists have defined learning as the exchange of messages in the brain caused by the biological, chemical and physiological changes that occur between neurons while transferring the information "provided by the sense organs" from one neuron to another (Liu & Chiang, 2014; Trevarthen, 1980; Wittrock, 1980). In other words, learning occurs as a result of reconnecting neurons after being affected by environmental or psychological conditions (Liu & Chiang, 2014).

Caine and Caine (1990) explained that the following principles are important in the teaching and learning process according to the Brain-Based Learning model**:**

- The brain is unique and a parallel processor (capable of multitasking).
- This arch for meaning goes through the brain's modeling process.
- Emotions are critical to the brain's modeling process.
- Learning includes both focused attention and environmental perception.
- Learning includes both conscious and unconscious processes.
- Learning always takes place in two memory approaches-keeping facts and making sense of skills, procedures and/or experiences**.**
- The brain can grasp and remember facts and skills embedded in the memory space.
- Complex and active experiences involving movements stimulate brain development.

Brain-Based Learning focuses on the physiological effects of learning. It relies on active learning strategies to engage the student cognitively using neuroscience principles (Jensen, 2008). There are many effective teaching and learning strategies for Brain-Based Learning including hypothetical thinking reversing, using different symbol systems, utilizing analogies, analyzing views/data, completion, mental maps, field trips, memory-supporting strategies, grouping, rhyming, acrostic, images and drama (Ramakrishnan & Annakodi, 2013). These strategies can also be used to improve learning skills by using the ways in which students feel most comfortable neurologically (Connell, 2009). One of these skills, metacognition, is now explained in detail.

Brain-Based Learning environment should promote positive emotions and experiences; less stress. Different teaching methods can be used for Brain-Based Learning to promote meaningful learning such as cooperation, discussion, utilizing technology, problem-based learning, storytelling, peer teaching, written and verbal information, drama, making or listening music, by breaking down difficult information into smaller and understandable pieces for students (Triana, Zubainur & Bahrun, 2019; Wittrock, 1992). Otherwise negative experiences, threatened classroom environment, uncomfortable emotions and unmanageable large piece of content cause students to downshifting which occurs if the student thinks that there are threatening elements in the learning process or in the learning environment (Saleh & Mazlan, 2019). During downshifting, learning does not occur because it effects the students' higher cognitive functions. In order to prevent this situation, emotionally safe and unthreatened learning environment should be prepared for students (Duman, 2010; Triana, Zubainur & Bahrun, 2019).

Metacognition

In his article "Metacognition and Cognitive Monitoring A New Area of Cognitive-Developmental Inquiry", Flavell first mentioned the concept of Metacognition (Flavell, 1979). He mentioned that metacognition and cognitive monitoring/regulation are interesting and promising new research areas. He describes metacognition is the individual's knowledge of their own cognitive processes, outcomes and structures. In trending studies in the field, the concept of metacognition is discussed under two main themes: metacognitive knowledge and metacognitive control (Pintrich, 2002). Metacognitive knowledge refers to the individual's own cognitive abilities, cognitive strategies and knowing what to do in accordance with the situation. Metacognitive control, also called metacognitive strategies, consists of mental processes that lead the metacognitive processes, and the ability to use metacognitive information strategically to achieve cognitive goals (Schwartz, Scott & Holzberger, 2013).

When the literature is examined, the concept of metacognition comes across as awareness, skill, learning strategy and teaching strategy. "Metacognitive awareness" means being aware of how you think and how you learn. Developing metacognitive awareness encompasses a very important learning skill that drives learners to be more effective and autonomous because being conscious of how you learn helps you identify the most effective ways to learn (Papaleontiou-Louca, 2019).

Metacognitive skill is one of the skills individuals should gain in life. When it comes to the learning strategies; they are the strategies used to be aware of learning situations and to organize learning experiences. In other words, metacognitive learning strategies enable students to improve the learning process by using functions such as gathering, lining up, planning and evaluation and to control their own cognition (Yen et al., 2018). These strategies are explained:

Renovation Strategy: It provides cognitive knowledge to students by repetition. Strategies are underlining, taking notes, taking notes with same words, writing without modifying, repeating, audible repetition (Weinstein & Mayer, 1983).

Interpretation Strategy: It provides connection between new knowledge and prior knowledge (Weinstein & Mayer, 1983). Strategies include interpreting data similar to what the learner may encounter in their daily life, weighing the evidence and deciding whether generalizations or conclusions based on the given data are warranted, participating in discussions and taking notes (Magno, 2010).

Organization Strategy: It enables the learner to reorganize his/her knowledge based on new information and includes strategies such as "extraction of main lines, tabulation and creation of information schema". (Weinstein & Mayer 1983).

Understanding Strategy: This is used to follow the concept. Strategies are controlling misperceptions, identifying and defining problems, gathering attention and directing reactions, correcting mistakes and producing solutions (Weinstein & Mayer 1983).

Affective Strategy: These strategies include reducing distracting instinctual factors. Strategies are focusing attention, developing a positive attitude, motivating, reducing anxiety, removing distracting objects, trust, managing performance anxiety, motivating oneself and using time effectively (Weinstein & Mayer 1983; Subası, 2000).

When metacognitive learning strategies are examined, it is seen that the Brain-Based Learning model can support these strategies. Examples of which metacognitive strategies are supported by Brain-Based Learning strategies are presented in the Table 1.

Table 1. Brain-Based Learning Strategies and Metacognition Strategies Examples

Brain-Based Learning strategies (Ramakrishnan & Annakodi, 2013)	Metacognition strategies (Weinstein & Mayer, 1983)
Talking: Students are allowed to talk to each other about the subject. This contributes to the cognitive learning of students by repeating the concepts aloud.	Renovation Strategy
Using images: Using posters, drawings, videos, pictures, etc. enables students to form mental images and supports memo	Interpretation Strategy
Making connections: The previously learned information is reviewed at the end of the lesson. It enables the learner to rearrange their knowledge.	Organization Strategy
Feedback: Students are informed about their work. It allows checking for false detections and correcting errors.	Understanding Strategy
Emotions: A positive environment is created by encouraging and praising students' efforts. It enables students to manage their performance anxiety and keep them motivated.	
Movement: Students are allowed to move during learning activities in the classroom. Being in motion helps focus attention.	
Music: Music is used in the learning environment. It provides association, relaxation and increased attention.	
Hydration: Students are allowed to drink water throughout the learning period. It eases anxiety management by reducing the stress caused by dehydration.	Affective Strategy
Opportunity to choose: Students are given the opportunity to sit wherever they want, to choose the activity material, and to determine the order of the lesson. It increases confidence in the classroom environment and supports the development of positive attitudes.	

As seen in Table 1, the Brain-Based Learning model and metacognitive strategies are similar in terms of including same strategies in teaching. Some studies (Oktay & Çakır, 2013; Fishman-Weaver, 2021) investigated this connection in a number of different aspects such as the 5E Model (Engagement, Exploration, Explanation, Elaboration and Evaluation) which is very popular one. This learning strategy is used to improve students' metacognition using the 5E instructional model (Feyzioğlu & Ergin, 2012; Turan & Matteson, 2021). This is because for conceptual change to occur, students need to experience conflict with their prior knowledge and the expectations. The new scientific concept or knowledge must be intelligible, plausible and useful in a variety of new situations (Posner et al., 1982).

In addition, in classrooms where teaching based on conceptual change is carried out, the individual characteristics of students should be considered, it is recommended to investigate different elements such as self-efficacy and motivation that affect learning (Feyzioğlu, Ergin & Kocakülah, 2012). Therefore, this learning environment is possible by means of the connections between the Brain-Based Learning, metacognition and the 5E model (Fishman-Weaver, 2021). In addition, Findings of a series of studies that examined the efficacy of this model in teaching Structures and Properties of Matter showed that the 5E model had positive effects on students' learning (Bybee, 2014; Grau, et al., 2021; Kujawski, 2014).

When the studies on metacognition are investigated, it has been noticed that the effects of different learning approaches on metacognition such as learning based on metacognition strategy (Kaufman & Randlett, 1983; Tei & Stewart, 1985; Chantharanuwong et al., 2012; Jaleel, 2016), problem-based learning (Bozan, 2008, Demirel & Turan, 2010), research-based learning (Ozkan & Bümen, 2014; Huertas et al., 2015), STEM education (Anwari et al., 2015), a number of others were investigated independently of Brain-Based Learning. It is seen that generally there are studies about the effects of Brain-Based Learning approach on mathematics education (Ozdemir & Sadık, 2019) and foreign language education (Khalil, Nagar & Awad, 2019). Most of the studies in the field of science related to Brain-Based Learning are about the attitudes towards science (Avcı, 2009; Tüfekçi & Demirel, 2009; Lim, Kim & Baek, 2012), academic achievement (Ozden & Gultekin, 2008; Jayapraba & Kanmani, 2013; Uçüncü & Sakız, 2018) and concept teaching (Bawaneh, et al., 2012; Saleh, 2012; Sani, Rochintaniawati & Winarno, 2019).

There are a limited number of studies investigating the effect of Brain-Based Learning on cognitive awareness. Oktay & Çakır (2013) investigated the effect of a technology-supported Brain-Based Learning approach on the metacognitive awareness level of 8th grade students. The result obtained by using the metacognitive awareness scale in the quasi-experimental study conducted is as follows; although there was an increase in the metacognitive awareness levels of both groups as a result of the application, there was no difference between the metacognitive awareness levels of the groups. Ghamdi (2019) aimed to determine the effect of the Brain-Based Learning model in a science class on the metacognitive abilities of primary school students. He revealed in his study that Brain-Based Learning increased students' metacognitive skills. The aim of this study is to contribute to the related literature by examining effects of the brain-based teaching method on seventh grade students' metacognitive awareness.

Method

Research Design

In this study, in order to analyze the effect of the Brain-Based Learning model on the metacognitive awareness of 7th grade students, the concurrent nested mixed method (Figure 1) was used. This is a method in which qualitative and quantitative data can be collected simultaneously or sequentially, and this also allows one data type to be embedded in another data type (Creswell, 2012; Creswell et al., 2014; Teddlie & Tashakkori, 2003). In this study, qualitative data are embedded in quantitative data. In the quantitative phase of the study, the one group pretest-posttest design was used. Qualitative data, on the other hand, were collected during the application (Creswell et al., 2014).

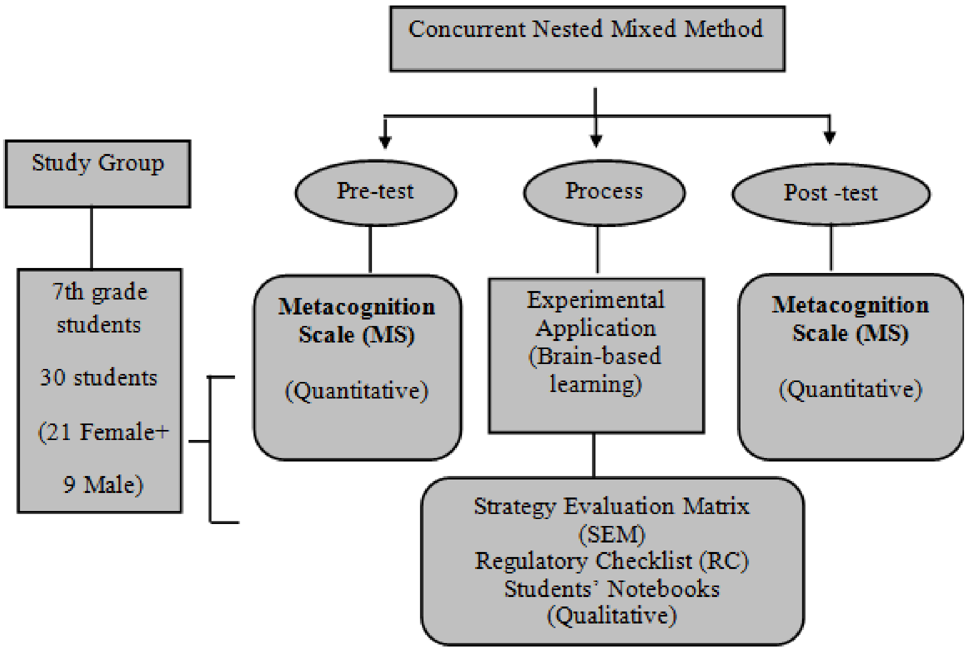

Figure 1. The Concurrent Nested Mixed Design Diagram of the Research

Sample

The study group was selected by the purposive sampling method, which is one of the non-probability sampling methods. The purpose of choosing this sampling method is to understand the relationships between the phenomena in depth and to discover the true meaning underlying the phenomenon (Merriam, 2009). The sample of the study consists of 30 seventh grade students. Students whose ages range from 12 to 13. The students voluntarily agreed to participate in this study.

Data Sources

Metacognition Scale (MS) was used as a quantitative data collection tool in the study (see Table 2). The qualitative data of the study were collected via Students' Notebooks, Strategy Evaluation Matrix (SEM), and A Regulatory Checklist (RC).

Table 2. Research Question and Data Collection Tools

Research Question	Quantitative Data Collection Tool	Qualitative Data Collection Tool
What is the effect of Brain-Based Learning (BBL) method on seventh grade students' metacognitive awareness?	Metacognition Scale (MS)	Strategy Evaluation Matrix (SEM) Regulatory Checklist (RC) Students' Notebooks

Metacognition Scale (MS)

Metacognition Scale was developed by Yıldız et al. (2009) for secondary school students (for 6th, 7th and 8th grade students). The scale consists of 30 items prepared in 4-Likert type response. Metacognition Scale includes eight factors: Declarative Knowledge, Procedural Knowledge, Conditional Knowledge, Planning, Self-control, Cognitive Strategies, Self-assessment and Self-monitoring (see Table 3). The Cronbach-Alpha internal consistency coefficient of the scale was calculated as 0.96.

Table 3. Dimensions and Sub-Dimensions of the Metacognitive Scale

Dimensions of Metacognition Scale	Sub-dimensions
Knowledge of Cognition	Declarative knowledge
	Procedural knowledge
	Conditional knowledge
Knowledge of Regulation	Planning
	Self-control
	Cognitive strategies
	Self-assessment
	Self-monitoring

Students' Notebooks

It consists of six chapters prepared by researchers for the Structure and Properties of the Matter Unit, aligned to topics to be covered over six weeks. In the first, third and sixth weeks, there are sections for students to draw their concept maps about matter. Also, there are open-ended questions (e.g. What kind of a mechanism could be in these mystery boxes to let strings to move in different directions?) prepared specifically for each week. Mystery boxes, making atom models, drama about scientists who worked on the structure of atoms and concepts cartoons about matter and atom activities were featured every week to let students be cognitively and physically active. They were encouraged to write down their feelings and thoughts at the end of each lesson. In this notebook, there are the Strategy Evaluation Matrix and Regulatory Checklist tables that students must fill out before each activity.

Strategy Evaluation Matrix

Strategy Evaluation Matrix, which was developed by Gursel (2016) and inspired by the Strategy Evaluation Matrix prepared by Schraw (1998), includes five basic strategies. These are repetition understanding, organizing, monitor understanding, and affective strategies (see Table 4). Students were asked to choose which of these strategies they will use before, during and after each cognitive task. The data from Strategy Evaluation Matrix were used to assess students' regulation of cognition.

Table 4. Strategy Evaluation Matrix (Gursel, 2016)

Learning Strategies	Declarative knowledge (About)	Procedural knowledge (How)	Conditional knowledge (Why and When)	Effects on Learning
Repetition Strategies	Underlining	Important words and points are underlined in the text.	While performing basic learning / reading	It allows distinguishing important points and speeds up recalling.
	Copying the notes	Important points are noted on the edge of the text.	While performing basic learning / reading	It enables us to learn information with mental repetition.
Understanding Strategies	Summarizing	The text is outlined and explained.	After the subject is processed / while reading	It provides to establish a relationship and integration between thoughts.
	Taking notes effectively	Explain the topic in your own words	After the subject is processed / while reading	Provides relation and integration between thoughts
Organizing strategies	Creating an information diagram	Important concepts in the text are shown together with their relationships.	During / at the end of topic-unit	Provides a gradual representation of the concepts in the text, the relationship is visualized.
	Tabulation	Main information is tabulated.	During / at the end of topic-unit	Information is visualized, grouped.
Strategies to Monitor Understanding	Checking for misunderstandings	The existence of something misunderstood in the learning process is questioned.	At the end of the topic	It reveals the efficiency of learning.
	Correcting errors and creating solutions	Misunderstood points are corrected and efforts are made to eliminate problems.	At the end of the topic	It ensures that the same mistakes are not repeated and thus progress is made.
Affective Strategies	Concentra- ting the attention	A suitable environment is prepared for learning. The person does not speak negatively to himself.	At every stage of the learning process	It increases the quality of learning.
	Managing performance anxiety	Feelings and thoughts that negatively affect learning are avoided.	At every stage of the learning process	A relaxed student grasps the topics better.

A Regulatory Checklist: Regulatory Checklist was developed by King' (1991) for secondary school students and consists of three parts: Planning, Monitoring and Evaluating (see Table 5). Students were asked to fill out the A Regulatory Checklist in every week. In the Planning part, students were asked to answer the four questions to indicate the time they will devote to working, the strategies they will use, their aims and the resources they will use. In the Monitoring section which students filled in while working on the subject, it was aimed to indicate their understanding of the activity, meaningfulness of the study, achievement of its goals, and whether or not they needed a change. At the end of the practice, students were asked to answer the questions in the Evaluating section, where they will state whether they have reached their goals, what works and what does not work and what to do differently next time.

Table 5. A Regulatory Checklist

A REGULATORY CHECKLIST	
Sub-dimensions	Questions to be answered
Planning	What is the nature of the task? What is my goal? What kind of information and strategies do I need? How much time and resources will I need?
Monitoring	Do I have a clear understanding of what I am doing? Does the task make sense? Am I reaching my goals? Do I need to make changes?
Evaluating	Am I reached my goal? What worked? What didn't work? Would I do things differently next time?

Context of the Study

Before the application, all of the lesson plans and Student Notebooks were prepared according to the Brain-Based Learning model which involves three main elements by using the 5E learning method (see Table 7). These elements are relaxed alertness, orchestrated immersion and active processing (Caine & Caine, 1990). Relaxed alertness is required to provide an optimal emotional climate, emotionally safe environment and positive classroom learning environment for students. In this stage, students need to feel encouraged and supported for open discussions, brainstorming activity or drawing concept map. During orchestrated immersion stage, students were encouraged to actively engage in hands-on and minds-on learning experiences, reflect on their experiences and concentrate on the content. At this stage, very strong sensory experiences should be included (Al-Balushi & Al-Balushi, 2018). Therefore, preparing challenging and rich environments, and enabling students to construct their knowledge by discovering concepts, processes and principles are essential for orchestrated immersion. Active processing is described as a situation in which students can associate their prior knowledge with the new knowledge they just learned. Writing short story or poetry, doing drama, role playing and discussion can be used as teaching methods that promote students actively participate in order to consolidate their learning (Duman, 2010).

Before the intervention, the Metacognition Scale was applied to students as a pretest. During the 6-week of implementation, the Strategy Evaluation Matrix, the Regulatory Checklist and Students' Notebooks were used (see Table 6) at the end of the intervention, and Metacognition Scale was applied as a posttest.

Table 6. Intervention during "Structure and Properties of Matters Unit"

Before the intervention	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	After the intervention
Brain Based Teaching Method							
Pre-test Metacognition Scale	Strategy Evaluation Matrix (SEM) A Regulatory Checklist (RC) Students' Notebooks						Post-test Metacognition Scale

During the application process, students' preliminary information was determined at the beginning of each course by using brainstorm and concept map activities. After that, students were required to fill Planning section of the Regulatory Checklist in Students' Notebook, and at the same time, they were asked to identify the strategies they wanted to use during the activity from the Strategy Evaluation Matrix. Afterwards the students planned their research. They started working and tried to reach answers of the questions they prepared by using the strategies they chose from the Strategy Evaluation Matrix. While the learning activity was going on, they filled in the Self-Monitoring part of the Regulatory Checklist. When the activity was completed, the Assessment section in the Regulatory Checklist was filled in by the students.

Table 7. Sample of Lesson Plan

5E Strategies	Brain-Based Learning Stages	Application
Engagement The teacher helps students to become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge.	Relaxed Alertness Creating the optimal emotional climate for learning. If a learning environment is reliable, attention periods occur at high level.	As teacher enters the classroom, she opens the windows. She shows the pictures of Salad and lemonade and then asks "What are the ingredients of these?", "how do they look ?", "Is there any difference between them?" Then teacher and students discuss these questions. Oxygen enters the classroom by opening the windows, so it Works brain. Students' attention is aroused with the help of pictures; they are motivated for lesson. Emotions and ideas are released thanks to discussion and also problem-based learning occurs with questions. Thus, relaxed alertness occurs.

Exploration Learners complete lab activities with their prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.	Immersion A person visualizes the knowledge in her/his mind.	Teacher distributes the worksheet about mixture for each student on 5 minutes Teacher separates students into 5 groups including 4 students and gives a worksheet about mixture with group in 7 minutes. The answers of groups are written in the board and teacher asks them to discuss questions such as can you explain result of your activity and encourages them to write their answers.
		When students learn new information, they code this information in their brains and so their number of dendrites increase. Immersion occurs when they express their ideas with their own words after discussion. Students focus the lesson with difficult questions, so downshifting is prevented.
Explanation Learners explain their understanding of the concept with critical thinking.		Teacher gives the first worksheet for each student to fill it again. Students' attention is increased again and pictures and writing on the worksheet help the different learning styles. Thus, both the cerebral hemispheres of brain are stimulated. Students envisage the new knowledge on the worksheet and immersion occurs.
Elaboration Students apply their understanding of the concept by new experiences.	Active Processing Brain constructs new knowledge by linking it person's daily life experiences.	Teacher and students discuss the answers of students on the board. Teacher wants students to give examples about homogeneous and heterogeneous mixtures from their daily life and write their notebooks. Teacher and students discuss whether the examples are right or not. Students' attention is increased and test their experiences with the help of daily life examples. Thus, active processing occurs. Students learn enjoyably by coding knowledge and they remember this knowledge by placing in long-term memory.
Assessment To understand to which degree students learn to content.	Active Processing	Formative evaluation is made using students' notebooks, assignments and activity reports.

In the Structure and Properties of Matter Unit areas were taught using the Brain-Based Learning Method: the structure of the atom and the basic particles in the structure of the atom; thoughts on atomic concepts from past to present; formation of ions; the formation of molecules; pure substances; mixtures; homogenous mixtures; heterogeneous mixtures and separation of mixtures (see Table 8).

Table 8. Subject Areas Studied Distribution by Weeks

Week	Subject	Duration (minutes)	Activity
1.	-Basic particles in the structure and structure of the atom -Thoughts on atomic concepts from past to present	40+40	- Analysis of newspaper news about Hiroshima and Nagasaki - Reading and discussion of Umberto Eco's "Bomb and the General" -Know what's in it. -Atomic model making activity from play dough
2.	-The Formation of ions -The formation of molecules	40+40	-Anion, cation or neutral? -Stable or unstable? -How many layers are there? -Atom or molecule? -Element or compound?
3.	-Pure compounds	40+40	-Mendeleyev's dream
4.	-Compounds	40+40	-What does our food and drink consist of?
5.	-Homogeneous Mixtures -Heterogeneous Mixtures	40+40	-Heterogeneous and homogeneous mixtures activity
6.	-Separation of Mixtures	40+40	- I am separating the mixtures.

Data Analysis

Quantitative data were analyzed using the SPSS 21 program, paired samples t-test for associated samples and one-way ANOVA for Repeated Measures for associated samples (repeated measurements). In the correlated measurements design, time-dependent repeated measurements of the same subjects are made before and after an experimental procedure (Büyüköztürk, 2014). Content analysis of the Regulatory Checklist, Strategy Evaluation Matrix, and student notebooks, through which the qualitative data of the study were collected, were performed. For validity and reliability, qualitative data were reviewed by two experts, independent of the researchers, and the consistency rate in the categories and themes was evaluated.

The Strategy Evaluation Matrices containing the strategies chosen by the students to use during their lesson were examined and the frequency tables of the strategies chosen by each student in each application and the graphs showing the weekly distribution of these strategies were created. The expressions used by students in the planning, self-monitoring and evaluation parts of the Regulatory Checklist have been graphed. In this way, it became possible to investigate the students who showed metacognitive development by making awareness of strategy choices and evaluating them after watching themselves.

Student notebooks helped the responses monitor the students' progress in a learning process. During the collection of qualitative data, the code name was given to the students in order to ensure the privacy of the students while selecting the samples. While creating the code name, a method such as K1 and K2 for female students and E1 and E2 for male students was followed.

Validity and Reliability of the Research

The fact that the study includes more than one variable increases the construct validity. Conduction of the application process by one of the authors increases the internal validity. In order to prevent an expectation about experimental conditions in the subjects and to prevent them from acting in accordance with these expectations, it was not stated to the subjects that they were in a research process. Since data collection was done with measurement tools, there was no researcher-participant interaction during data collection, and this increased external validity.

The fact that the pre-test was applied increases the external validity (Büyüköztürk, 2014). In terms of validity and reliability of qualitative data, the theme creation process was carried out together with researchers and two field experts. The agreement among the evaluators was calculated with the formula of Reliability = Agreement / (Agreement + Disagreement) × 100) stated by Miles & Huberman (1994) and this value was found 0.76 which is acceptable (Yıldız, et al., 2009).

Results

Paired samples t-test was used for dependent samples to test whether there is a statistically significant difference between the Metacognition Scale pretest and posttest scores. When Table 9 is analyzed, the pre-test average of the students in the study group was 94.63 while the post-test average was found to be 99.36. Looking at the pre-test and post-test scores, it is seen that the post-test scores are higher. However, this difference between pre and post test scores was not significant ($p = .125$, $p > .05$), showed that there was no significant increase in the metacognitive levels of the students after the six-week practice using the Brain-Based Learning method ($t(29) = -1.579$, $p > .05$).

Table 9. Associated t-Test Results of Metacognitive Scale Pre-Test and Post-Test Scores

Groups	N	Mean	S	sd	t	p
Pre-test	30	94.63	15.86	29	-1.579	0.125
Post-test	30	99.36	12.23			

Dependent samples t-test was applied to analyze the pre-test and post-test averages of the students' Metacognition Scale on the basis of sub-dimensions (see Table 10). While the pre-test mean score was 52.50 in the Knowledge of Cognition sub-dimension, it was found to be higher at 57.86 by increasing the average score in the post-test. There is a statistically significant difference between pretest and posttest of the Knowledge of Cognition sub-dimension (p = .001, p <.05).

Table 10. Cognitive Knowledge and Regulation of Cognition Sub-Dimensions of the Metacognitive Scale Pretest-Posttest Dependent Samples t-test Results

Dimensions of MS		N	Mean	S	t	sd	p
Knowledge of Cognition (KC)	Pre-test	30	52.50	8.84	-3.759	29	.001*
	Post-test	30	57.86	4.24			
Knowledge of Regulation (KR)	Pre-test	30	38.70	6.85	-1.505	29	.143
	Post-test	30	41.50	9.35			

Dependent samples t-test was applied to analyze the pre-test and post-test averages of the students in the Knowledge of Cognition which is required students to answer what, how, why and when questions about the subject, dimension on the basis of factors (see Table 11).

Table 11. Dependent Samples t-test Results of Factors in the Knowledge of Cognition (KC) Sub-Dimension

Sub-dimension of KC		N	Mean	S	t	sd	p
Declarative Knowledge (DK)	Pre-test	30	29.56	4.76	-1,193	29	.243
	Post-test	30	30.60	2.45			
Procedural Knowledge (PK)	Pre-test	30	13.86	2.35	-0,068	29	.946
	Post-test	30	13.90	1.42			
Conditional Knowledge (CK)	Pre-test	30	12.50	2.73	-1,975	29	.048*
	Post-test	30	13.36	1.93			

For the conditional knowledge, which is the one of the Knowledge of Cognition, there was a statistically significant difference between pretest and posttest (p = .048, p <.05). It was determined There was no statistically significant difference between pretest and posttest of both Declarative Knowledge (p=.243, p<.05) and Procedural Knowledge (p=.946, p<.05).

Dependent samples t-test was applied to analyze the pre-posttest averages of the students in the Knowledge of Regulation sub-dimension on the basis of Planning, Self-control, Cognitive Strategies, Self-Assessment and Self-monitoring factors (see Table 12). It has been determined that the difference between the pre and post-test averages of the factors that made up the Group's Knowledge of Regulation were not statistically significant. The qualitative data, used to support the quantitative data, were obtained from the Strategy Evaluation Matrix, A Regulatory Checklist and student notebooks, and the analysis results were presented below.

Table 12. Dependent Sampling t-test Results for Knowledge of Regulation Sub-dimension Factors

Sub-dimension of RK		N	Mean	S	t	sd	p
Planning	Pre-test	30	6.53	1.22	0.108	29	.915
	Post-test	30	6.50	1.13			
Self-control	Pre-test	30	8.70	2.11	-1.628	29	.114
	Post-test	30	11.03	7.93			
Cognitive strategies	Pre-test	30	8.90	1.78	-0.921	29	.365
	Post-test	30	9.20	1.44			
Self-assessment	Pre-test	30	9.33	1.74	0.081	29	.936
	Post-test	30	9.30	1.36			
Self-monitoring	Pre-test	30	5.23	1.61	-0.630	29	.534
	Post-test	30	5.46	1.59			

Strategy Evaluation Matrix

In the Strategy Evaluation Matrix, 10 different techniques consisting of five different strategies were given to the students to choose (see Table 4). When the Table 13, which is the frequency of choosing different techniques for the strategies, was examined, it was seen that Affective Strategies are the most chosen and the Understanding Monitoring Strategies was the least chosen in all weeks.

Table 13. Strategy Use Weekly and General Frequency

Strategies	Techniques	1st week	2nd week	3rd week	4th week	5th week	6th week	Total	Grand total
Repetition Strategies	Underlining	15	6	2	-	-	-	23	39
	Copying the notes	2	1	4	7	1	1	16	
Understanding strategies	Summarizing	5	3	-	1	-	-	9	22
	Taking notes effectively	3	5	5	-	-	-	13	
Organizing strategies	Creating on information diagram	-	-	-	-	-	-	-	30
	Tabulation	1	1	1	7	11	9	30	
Strategies to monitor understanding	Checking for misunderstanding	1	1	1	-	4	3	10	10
	Correcting errors and creating solutions	-	-	-	-	-	-	-	
Affective strategies	Focusing the attention	7	3	11	2	11	7	41	44
	Managing performance anxiety	-	-	-	1	1	1	3	

*Metacognitive awareness increases as one goes from repetition strategies to affective strategies.

When the preferred techniques were examined, it was determined that the technique of Concentration of Attention was used the most. It has been observed that Information Schematic Creation, Error Correction and Solution Generation techniques were not preferred at all. When the weekly distributions of the usage of strategies were reviewed, it was seen that the frequency of choosing Tabulation from Organizing Strategies, Controlling Misunderstanding from Understanding Strategies and Concentrating Attention from Affective Strategies showed tendency to increase. Underlining the Articles, Taking Exact Notes, Summarizing, and Taking Efficient Notes were among the techniques that show a decreasing trend.

When Table 13 is examined, frequencies of some techniques such as underlining, summarizing, and focusing attention were higher than the other techniques, since reading was made on the information papers in the first week. Because there was a course presentation in the second week, it was seen that the rate of copying the notes increases, unlike the first week. In the third week, it was evaluated that the frequencies of focusing attention, copying notes, and efficient note-taking increased because of the activity of taking notes by listening to songs. It was observed that the frequencies of focusing attention and tabulation strategies increased.

Regulatory Checklist

When the expressions stated by the students in the evaluation section of the Regulatory Checklist table were analyzed, it was observed that the students stated more and more that they reached their goals in process of the weeks. The students stated that a majority of the strategies they used time in the first, third, fifth and sixth weeks worked for them and that they achieved their goals. When Figure 2 and 3, which were created using the data in the Regulatory Checklist table, are analyzed, it was observed that the awareness of the students increased as they progressed in strategies from Strategy Evaluation Matrix.

Figure 2. Students' Self-evaluation of Their Work

It was seen that as the awareness of the students increased, the rate of achieving their goals increases (see Figure 4). It was seen that as the students gained experience and started to be conscious and to think while choosing strategies to implement for their learning.

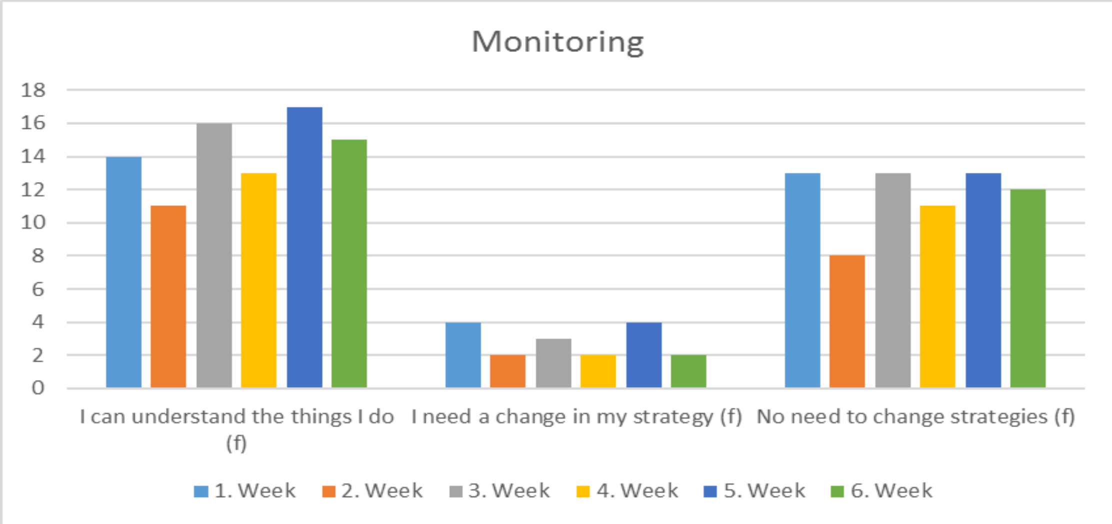

Figure 3. Students' Evaluations of the Strategies They Choose from SDM According to Weeks

Figure 4. Students' Level of Understanding the Purpose of the Course According to Weeks

Students' Notebooks

When the notes written by the students in their notebooks about the course are reviewed, in the fifth week the student K1 stated that *"….about what's in the box activity, I'm still curious. The box mechanism, it was educational and thought-provoking*." K12 said that, "*I really like the atomic models I make, I like them even more i when I saw them on the bulletin board. I think every class should have visuals like this*. "Regarding this activity, E6 said, "*The events we did were very fun. I had a lot of fun doing the atom models …… I had a great day* "The student E3 said, *"Actively engaging in the subjects was very enjoyable and educational…. I realized that by doing and engaging in activities make knowledge more permanent ... enjoying the science class. It would have been very nice to have this kind of instructional method all the time*. "

It was clear that students enjoyed Brain-Based Learning practices and their motivation and attitude towards the lesson developed positively. Some students said that they always wanted to receive training that includes such practices. Moreover, it was observed that the awareness of students about their own learning also increased.

Discussion and Conclusion

When the results obtained in this study conducted to determine the effect of the Brain-Based Learning method on the metacognitive awareness of seventh grade students were evaluated, it was found that there was no statistically significant difference between the Metacognition Scale pretest-posttest results, but there was a statistically significant difference in the Knowledge of Cognition, one of the sub-dimensions of the scale. When the factors in the Knowledge of Cognition sub-dimension were considered, a statistical difference was found between the Conditional Knowledge's pretest and posttest results. This shows that students' metacognitive knowledge about when and why to use various cognitive actions, explanatory and methodological information improved during the study process. Conditional Knowledge also enables students to adjust the requirements of the changing situations of each learning task (Schraw, 1998). Individuals with high Conditional Knowledge are better at measuring the needs of a particular learning situation and in this way, they can choose the most appropriate strategy for the situation (Schraw et al., 2006).

As a result of statistical analysis, it was determined that the difference between the pre and post-test averages of the Declarative Knowledge and Procedural Knowledge factors was not statistically significant. In other words, there was no awareness in the factors of Declarative Knowledge, which explains the person's knowledge of himself as a learner and Procedural Knowledge, which includes the factors affecting person's performance, the knowledge of her work, strategies and other processes such as the application of procedural skills. Considering the results obtained from Planning, Self-control, Cognitive Strategies, Self-Assessment and Self-monitoring factors, it was found that the difference between the pre-test and post-test averages of the study group was not statistically significant.

The findings obtained from the Strategy Assessment Matrix, one of the qualitative data collection tools, showed that students used high-level strategies (Affective Strategy) and techniques (Concentration of Attention), thus the Brain-Based Learning approach increased students' metacognitive awareness. This finding was consistent with Conditional Knowledge. The difference between pretest and posttest of Conditional Knowledge was found statistically significant in the sub-dimensions of the Metacognition Scale and expresses the knowledge about choosing the appropriate strategy by answering the questions of why, when and where in the learning process of individuals. When the techniques preferred by the students in the Strategy Evaluation Matrix are examined, it was determined that the technique of Concentrating Attention was used the most. It was observed that Information Schematic Creation, Error Correction and Solution Generation techniques were not preferred at all. Gursel (2016) found similar results in his study.

When the expressions stated by the students in the evaluation section of the Regulatory Checklist were reviewed, they stated that as the process progressed, their awareness increased and the strategies they used worked. It was observed that as the awareness of the students increased, the rate of achieving their goals increased and they started to be conscious and think while choosing strategies. Kılıc & Beyazıt (2019) reached similar results in their study. The development of metacognitive skills is very important for individuals to learn by themselves and to increase their awareness of how to learn. Because metacognitive skills allow individuals to control and evaluate their own thoughts and learning (Peters, 2000; Rivers, 2001). In this study using the BBL model, it was observed that the metacognitive skills of the students, their ability to choose the most appropriate strategies and techniques for their own learning improved.

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