

Visual Knowledge Representations and the Quality of Teaching Natural and Life Sciences:

A Field Study from the Perspective of Middle School Teachers

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Abstract

This study aimed to identify the role of visual knowledge representations in improving the quality of teaching natural and life sciences from the perspective of middle school teachers. Specifically, it examined the extent to which visual representations, particularly concept maps and explanatory diagrams, contribute to the organisation of scientific content, facilitating its comprehension and summarisation in a manner that positively impacts the quality of the teaching process. The study adopted a descriptive-analytical approach. A 26-item questionnaire, divided into two dimensions, was administered to a sample of 52 male and female teachers of natural and life sciences. The data were analysed using the Statistical Package for the Social Sciences (SPSS), with frequencies, percentages, arithmetic means, standard deviations and Cronbach's alpha reliability coefficient being relied upon.

The findings revealed a high level of agreement among participants on the positive impact of visual knowledge representations on the quality of subject teaching. These representations were found to clarify and organise scientific concepts, and highlight the relationships between them. They also supported the systematic summarisation of instructional content, helped learners to connect new knowledge with prior knowledge, developed analysis and recall skills, and improved academic achievement, particularly among low-achieving learners. The findings further supported both sub-hypotheses, thereby corroborating the general hypothesis that visual knowledge representations improve the quality of Natural and Life Sciences teaching at middle school level.

Keywords: visual knowledge representations; teaching quality; Natural and Life Sciences; middle school education; concept maps; explanatory diagrams.

Introduction

Education in the twenty-first century is undergoing rapid transformation, driven by the digital revolution and the explosion of knowledge. These developments have led to a substantial increase in the volume and complexity of information, making it increasingly difficult for learners to acquire knowledge through traditional teaching methods that focus primarily on transmission and memorisation. In response to this, educational systems are

adopting contemporary approaches that emphasise knowledge construction, the development of thinking skills, and learners' ability to organise, analyse, and apply information in diverse learning situations, in line with the requirements of lifelong learning.

In this context, constructivist approaches to learning have emerged as a foundation for developing teaching practices. These approaches emphasise that meaningful learning occurs when learners construct knowledge for themselves by connecting new information with prior experience, recognising relationships among concepts, and organising these concepts into interconnected cognitive structures. Building on this, instructional strategies and tools that visualise knowledge have emerged as effective ways of organising and acquiring knowledge (Al-Khafaji et al., 2023, p. 28).

Visual knowledge representations are a contemporary trend in learning design. They involve transforming abstract knowledge into organised visual forms, such as knowledge maps, concept maps, organisational diagrams, semantic networks and schematic representations. This makes relationships between concepts and ideas clearer and more interconnected. They play a vital role in facilitating deep understanding, critical thinking, systems thinking, and the efficient analysis, organisation, and retrieval of knowledge. They also help to reduce cognitive load and improve memory and comprehension processes.

A substantial body of educational research has demonstrated that using visual knowledge representations can enhance learning outcomes, increase learner motivation, strengthen classroom interaction and foster self-directed learning skills. They can also help to identify and correct misconceptions, enabling teachers to present scientific content more clearly and coherently. Such representations have also become a key component of digital learning environments due to their ability to support interactive learning and higher-order cognitive skills (Nesbit & Adesope, 2006).

These approaches are particularly important in teaching Natural and Life Sciences, as this subject includes interrelated scientific concepts, biological processes, causal relationships and scientific classifications which may be difficult to understand through verbal presentation alone. Visual knowledge representations allow learners to build an integrated mental image of scientific concepts and understand the relationships between their components. They also enable learners to connect theoretical knowledge with practical applications, which can positively influence the quality of learning and academic achievement.

In light of contemporary trends that advocate active learning, knowledge construction and visual learning, it is important to examine how visual knowledge representations are actually used in the teaching of natural and life sciences, and to determine their contribution to improving teaching practices from the perspective of teachers, who are primarily responsible for implementing curricula and achieving their objectives.

Accordingly, the present study, entitled 'Visual Knowledge Representations and the Quality of Teaching Natural and Life Sciences: A Field Study from the Perspective of Middle School Teachers', aims to investigate the use of visual knowledge representations in teaching Natural and Life Sciences, examining their contribution to improving teaching quality, clarifying scientific information and organising instructional content to enhance teaching

practices and promote more effective learning. The research problem is therefore formulated in the following main question:

To what extent do visual knowledge representations contribute to improving the quality of teaching Natural and Life Sciences from the perspective of middle school teachers?

Sub-questions

1. To what extent do visual knowledge representations contribute to clarifying scientific concepts and enhancing their understanding in the teaching of Natural and Life Sciences from the perspective of middle school teachers?
2. To what extent do visual knowledge representations contribute to organizing and summarizing the scientific content of Natural and Life Sciences from the perspective of middle school teachers?

Study Hypotheses

General Hypothesis

Visual knowledge representations contribute to improving the quality of teaching Natural and Life Sciences from the perspective of middle school teachers.

Sub-hypotheses

1. Visual knowledge representations contribute to clarifying scientific concepts and information in Natural and Life Sciences from the perspective of middle school teachers.
2. Visual knowledge representations contribute to organising and summarising the scientific content of Natural and Life Sciences from the perspective of middle school teachers.

Importance of the Study

The importance of this study stems from contemporary educational trends that emphasise the need to employ visual knowledge representations in the educational process because of their role in organising knowledge, simplifying scientific concepts, and promoting meaningful learning. The significance of the study can be summarized as follows:

- Highlighting the importance of visual knowledge representations as a contemporary approach that can improve the quality of teaching Natural and Life Sciences by clarifying scientific concepts and organising instructional content more effectively.
- Providing middle school teachers with an evidence-based perspective on the importance of employing visual knowledge representations in teaching practices, thereby encouraging the adoption of contemporary teaching strategies aligned with twenty-first-century learning requirements.
- Identifying the actual use of visual knowledge representations in teaching Natural and Life Sciences from the perspective of middle school teachers, thereby helping diagnose strengths and areas in need of further development.
- Contributing to the enrichment of Arabic-language scholarship on visual knowledge representations and providing a reference that may inform future studies concerned with the development of science teaching.
- Providing empirical findings that curriculum developers and training-program designers may use to support the integration of visual knowledge representations into classroom environments.

Objectives of the Study

The present study seeks to achieve the following objectives:

1. To identify the actual use of visual knowledge representations in teaching Natural and Life Sciences from the perspective of middle school teachers.
2. To determine the extent to which visual knowledge representations contribute to clarifying scientific concepts and information in Natural and Life Sciences.
3. To determine the extent to which visual knowledge representations contribute to organising and summarising scientific content in ways that improve the quality of teaching Natural and Life Sciences.

Operational Definitions of the Study Concepts

1. Visual Knowledge Representations

Visual knowledge representations are organizational tools that present knowledge in a visual form that clarifies concepts and the relationships among them in hierarchical or network structures. They help learners organise knowledge, connect new concepts with prior experience, and construct meaningful learning. They also contribute to improved understanding, comprehension, retrieval, and thinking. This form of representation is among the most effective tools for organizing and facilitating the learning of scientific content, particularly in subjects that involve interconnected concepts and relationships (Novak & Cañas, 2008).

In the present study, visual knowledge representations refer to all visual tools and media used by Natural and Life Sciences teachers during instruction, including concept maps, knowledge maps, organisational diagrams, and illustrations, with the aim of organising scientific content, highlighting relationships among concepts, and clarifying and summarising the content in ways that improve the teaching process. This variable is measured through the participants' responses to the questionnaire items.

2. Quality of Teaching Natural and Life Sciences

In this study, the quality of teaching Natural and Life Sciences refers to the level of effectiveness of teaching practices associated with the use of visual knowledge representations to clarify scientific concepts and to organise and summarise instructional content, as perceived by middle school teachers. It is measured by the total score obtained by participants across the two questionnaire dimensions.

3. Middle School Teachers

This term refers to all teachers of Natural and Life Sciences working at the middle school level in the municipalities of Aïn M'lila and Souk Naamane, Oum El Bouaghi Province, who constitute the study population and sample.

4. Natural and Life Sciences

The National Curriculum Committee (2013, p. 138) defines Natural and Life Sciences as a scientifically oriented educational subject concerned with the gradual development of learners' scientific knowledge and competencies. It enables learners to understand, explain, and deal with natural phenomena according to the scientific method, thereby developing scientific thinking and strengthening their ability to apply knowledge to problem solving and to interact effectively with their environment.

In this study, the term refers to the school subject prescribed at the middle school level in accordance with the official Algerian curriculum and taught by Natural and Life Sciences teachers using the visual knowledge representations examined in this study.

Field Study and Methodological Procedures

Study Method

The study adopted the descriptive-analytical method because of its suitability to the nature and objectives of the research. This method was used to describe the actual employment of visual knowledge representations in teaching Natural and Life Sciences and to analyse middle school teachers' views regarding their contribution to improving teaching quality through the systematic collection, analysis, and interpretation of data.

Study Population and Sample

The study population consisted of all Natural and Life Sciences teachers working at the middle school level in the municipalities of Aïn M'lila and Souk Naamane, Oum El Bouaghi Province, totaling 52 teachers.

A purposive sampling approach was adopted. Because the number of subject teachers in the educational institutions included in the study was limited, all members of the population were included. Accordingly, the sample consisted of 52 teachers and represented the entire target population.

Study Setting

The study was conducted in 14 middle schools distributed across the municipalities of Aïn M'lila and Souk Naamane, Oum El Bouaghi Province, as shown in Table 1.

Table 1. Distribution of the Educational Institutions Included in the Study

Municipality	Educational institutions	Number
Aïn M'lila	Mohamed El Djilali Beroual; Hocine Khelifi; El Tehami Guerabsi; Abdallah Seboua; Ali Guelab; Dhebih Slimane; Zahad Mohamed; El Fourchi Okacha; Mohamed Ghrab; Aissa Tournch Touhami	10
Souk Naamane	Annab Naamoun; Ibn Kessas Khalifa; Arab Mesbah; Aissa Siga	04
Total	Middle schools in Aïn M'lila and Souk Naamane	14

Study Instrument

The questionnaire was used as the principal data-collection instrument because of its suitability to the descriptive nature of the study and its ability to collect participants' views regarding the use of visual knowledge representations in teaching Natural and Life Sciences.

The questionnaire was developed in light of the study objectives, the theoretical framework, and previous studies, while also drawing on the findings of the pilot study and preliminary interviews with a number of Natural and Life Sciences teachers. This process was intended to ensure adequate coverage of the topic's dimensions and accurate measurement of the study variables.

Questionnaire Construction

In its final form, the questionnaire consisted of 26 items distributed across two main dimensions:

- Dimension 1: The contribution of visual knowledge representations to clarifying scientific concepts and information in the teaching of Natural and Life Sciences (14 items).
- Dimension 2: The contribution of visual knowledge representations to organising and summarising the scientific content of Natural and Life Sciences (12 items).

The questionnaire items were formulated on the basis of relevant educational literature, findings from previous studies, and the results of the pilot study, in order to ensure alignment with the study objectives and dimensions.

Psychometric Properties of the Study Instrument

The psychometric properties of the instrument were examined to ensure its suitability for field application. Validity and reliability were assessed as follows:

Expert Validity (Face Validity)

The preliminary version of the questionnaire was submitted to three faculty members specializing in educational sciences and psychology at Abdelhamid Mehri University – Constantine 2. They were asked to assess the relevance of the items to the study topic, the linguistic accuracy and clarity of the wording, and the extent to which each item belonged to the dimension it was intended to measure. The review process resulted in suggestions to reword, delete, or modify several items in line with the study objectives. All comments were taken into consideration before the questionnaire was adopted in its final form.

Instrument Reliability

To assess the reliability of the study instrument, Cronbach's alpha internal-consistency coefficient was calculated using SPSS to determine the consistency of the questionnaire items in measuring the study construct.

Table 2. Questionnaire Reliability Using Cronbach's Alpha

Q uestionnaire as a whole	Overall reliability coefficient
26 items	0.87

As shown in the table, the overall reliability coefficient of the questionnaire was 0.87. This high value indicates a strong level of reliability and internal consistency among the items, supports the instrument's suitability for field application, and strengthens confidence in the findings and in the instrument's use for testing the study hypotheses and achieving its objectives.

Statistical Methods

After the field data were collected, they were processed and analysed using the Statistical Package for the Social Sciences (SPSS) in order to obtain statistical indicators appropriate to the nature and objectives of the study and to test its hypotheses. The following statistical procedures were used:

- Frequencies and percentages to describe participants' responses to the questionnaire items.
- Arithmetic means to determine the level of participants' responses across the study dimensions.
- Standard deviations to measure the dispersion of responses around the arithmetic means.

Table 3. Middle School Teachers' Responses to Dimension 1: The Role of Visual Knowledge Representations in Clarifying the Scientific Content of Natural and Life Sciences

Item	Statement	Yes n (%)	To some extent n (%)	No n (%)	Mean	SD
01	Visual knowledge representations help connect prior knowledge with new knowledge.	28 (54%)	20 (38%)	4 (8%)	2.44	—
02	Visual knowledge representations help clarify the basic concepts of the lesson.	41 (79%)	11 (21%)	0 (0%)	2.78	0.26
03	Visual knowledge representations help organise lesson elements from the general to the specific.	52 (100%)	0 (0%)	0 (0%)	3.00	0.30
04	Visual knowledge representations facilitate the communication of information to learners.	30 (58%)	12 (23%)	10 (19%)	2.38	0.20
05	Visual knowledge representations help identify learners' misconceptions or incorrect conceptions.	33 (62%)	19 (38%)	0 (0%)	2.63	0.24
06	Visual knowledge representations help learners organise the essential information related to the subject.	40 (77%)	12 (23%)	0 (0%)	2.76	0.26
07	Visual knowledge representations help learners develop a comprehensive grasp of the information related to the lesson topic.	32 (62%)	20 (38%)	0 (0%)	2.61	0.24
08	Visual knowledge representations enable learners to identify their own errors.	34 (65%)	18 (35%)	0 (0%)	2.65	0.24
09	Visual knowledge representations provide a comprehensive overview of the lesson topic.	52 (100%)	0 (0%)	0 (0%)	3.00	0.30
10	Visual knowledge representations take individual differences among learners into account.	30 (58%)	18 (35%)	4 (8%)	2.50	0.22
11	The use of visual knowledge representations contributes to making better use of class time.	13 (25%)	35 (67%)	4 (8%)	2.17	0.20
12	Visual knowledge representations increase learners' attention to the lesson.	49 (94%)	3 (6%)	0 (0%)	2.94	0.30
13	Visual knowledge representations strengthen feedback among learners and between the teacher and learners.	40 (77%)	12 (23%)	0 (0%)	2.76	0.26
14	Visual knowledge representations help assess learners' understanding of the	42 (81%)	10 (19%)	0 (0%)	2.80	0.26

	information presented.					
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Interpretation of the Results in Light of the First Sub-hypothesis

Table 3 presents the participants’ responses to the first dimension, which corresponds to the first sub-hypothesis stating that visual representations contribute to clarifying the content of Natural and Life Sciences from the perspective of middle school teachers. The results indicate that most participants expressed a high level of agreement with the statements in this dimension. Standard deviation values ranged from 0.20 to 0.30, which are low values that reflect the convergence of participants’ responses and their agreement regarding the importance of using visual representations in teaching the subject.

Items 3 and 9 recorded the highest agreement rate at 100%. All teachers confirmed that visual representations help organise and sequence lesson content from the general to the specific and provide a comprehensive and integrated overview of the lesson topic. This finding may be explained by the ability of visual representations to organize scientific knowledge in an interconnected form, thereby making it easier for learners to recognize relationships among concepts and understand the structure of scientific content as an integrated whole.

Item 12 ranked second, with an agreement rate of 94%. Teachers reported that visual representations enhance learners’ attention and motivation toward lesson content, highlighting their role in making learning more engaging and interactive, particularly in Natural and Life Sciences, which includes numerous abstract concepts and processes.

The results also showed a high agreement rate for Item 14 (81%), indicating that visual representations help teachers assess the extent to which learners have understood scientific concepts. This finding reflects their importance not only in presenting knowledge but also in monitoring learning and identifying learners’ level of understanding of scientific content.

Items 6 and 13 each recorded an agreement rate of 77%, indicating that participants agreed that visual representations help organise essential scientific information in an interconnected manner and enhance feedback and interaction between teachers and learners during instruction, thereby positively affecting the quality of the teaching-learning process.

Item 2 achieved an agreement rate of 79%, with teachers confirming that visual representations contribute to clarifying the basic scientific concepts of lesson content. Items 5 and 7 each recorded an agreement rate of 62%, suggesting that visual representations help identify learners’ misconceptions and support a broader understanding of the various components of scientific content, thereby contributing to more accurate scientific understanding.

Item 8 recorded an agreement rate of 65%, confirming that visual representations help learners identify and correct their conceptual errors. Items 4 and 10 each recorded 58%, reflecting the role of visual representations in simplifying and clearly communicating scientific information while taking individual differences in conceptual understanding into account.

For Item 1, the agreement rate was 54%, indicating that visual representations contribute to a good degree to linking prior knowledge with new knowledge. This is a fundamental principle of meaningful learning because it helps learners integrate new experiences into their existing cognitive structures.

By contrast, Item 11 recorded the lowest agreement rate (25%), while 67% of participants selected “to some extent.” This suggests that the contribution of visual representations to more efficient use of class time remains dependent on the nature of the instructional content, the availability and readiness of teaching

resources, the density of the curriculum, and the amount of instructional time allocated to Natural and Life Sciences.

Overall, the findings confirm that middle school teachers view the use of visual representations in teaching Natural and Life Sciences positively because of their role in organising scientific knowledge, clarifying concepts, enhancing understanding, and encouraging learners to interact with instructional content. Accordingly, the first sub-hypothesis stating that visual representations contribute to clarifying the content of Natural and Life Sciences from the perspective of middle school teachers was supported.

Table 4. Middle School Teachers' Responses to Dimension 2: The Role of Visual Knowledge Representations in Summarizing the Scientific Content of Natural and Life Sciences

Item	Statement	Yes (%) n	To some extent (%) n	No (%) n	Mean	SD
15	The visual-representation strategy helps in preparing summaries of the lessons presented.	32 (62%)	20 (38%)	0 (0%)	2.61	0.24
16	Visual representations enable learners to connect new information with prior knowledge.	52 (100%)	0 (0%)	0 (0%)	3.00	0.30
17	Visual representations help learners distinguish between similar concepts and information.	30 (58%)	17 (33%)	5 (9%)	2.48	0.28
18	I take the organization and sequencing of information into account when preparing summaries using visual representations.	50 (96%)	2 (4%)	0 (0%)	2.96	0.30
19	I use visual representations to highlight relationships among concepts and the main ideas of the lesson.	20 (38%)	22 (43%)	10 (19%)	2.19	0.22
20	The visual-representation strategy contributes to developing learners' analysis and synthesis skills.	42 (81%)	10 (19%)	0 (0%)	2.80	0.26
21	Visual representations help learners retain scientific information and retrieve it over longer periods.	42 (81%)	10 (19%)	0 (0%)	2.80	0.26
22	I ask learners to prepare lesson summaries using visual representations.	22 (42%)	30 (58%)	0 (0%)	2.42	0.20
23	Visual knowledge representations facilitate the review of scientific content in preparation for examinations.	30 (58%)	16 (31%)	6 (11%)	2.46	0.22
24	Visual knowledge representations contribute to improving the achievement of low-performing learners.	45 (87%)	7 (13%)	0 (0%)	2.86	0.28

25	At the end of each lesson or instructional unit, I prepare a summary in the form of a visual knowledge representation.	52 (100%)	0 (0%)	0 (0%)	3.00	0.30
26	I assess summaries produced as visual representations according to specific criteria.	40 (77%)	9 (17%)	3 (6%)	2.71	0.24

Interpretation of the Results in Light of the Second Sub-hypothesis

The results presented in Table 4, which concern the second dimension and the second sub-hypothesis stating that visual knowledge representations contribute to summarising the content of Natural and Life Sciences from the perspective of middle school teachers, show that most participants agreed with the statements in this dimension. This is reflected in the high percentages and arithmetic means, which ranged from 2.19 to 3.00, together with low standard deviation values ranging from 0.20 to 0.30. These values indicate convergence in participants' views and agreement regarding the positive role of visual representations in summarizing instructional content.

Items 16 and 25 ranked first, each with an agreement rate of 100%. Item 16 indicates that visual representations enable learners to connect new information with prior knowledge, which is consistent with the principles of meaningful learning. Organizing knowledge visually helps integrate new experiences into learners' existing cognitive structures, making learning more comprehensible and meaningful. Item 25, which concerns preparing a visual summary at the end of each lesson or instructional unit, reflects teachers' awareness of the importance of presenting scientific content in an organized and interconnected form that enables learners to identify the most important ideas and key concepts.

Item 18 ranked second, with an agreement rate of 96%. This item emphasizes organizing and sequencing information when preparing summaries using visual representations and highlights the importance of hierarchical organization of concepts in improving understanding of scientific content and making relationships among its elements explicit, thereby facilitating comprehension and retrieval.

Item 24 achieved an agreement rate of 87%, indicating that most teachers agreed that visual representations contribute to improving the achievement of low-performing learners. This may be explained by their ability to simplify scientific content and transform it into visual forms and relationships that facilitate the understanding of abstract concepts and help this group of learners organize and acquire knowledge more effectively.

Items 20 and 21 each achieved an agreement rate of 81%. Teachers considered visual representations effective in developing learners' analysis and synthesis skills and in helping them retain and retrieve scientific information over longer periods. This reflects the cognitive role of visual representations in analyzing concepts and linking them within an organized knowledge structure, thereby consolidating learning and improving memory and recall.

Item 26 recorded an agreement rate of 77% and refers to teachers' assessment of summaries produced in the form of visual representations according to specific criteria. This indicates that teachers not only assign learners to prepare such summaries but also evaluate them using educational criteria related to the clarity of the visual representation, the accuracy of concepts, their logical sequencing, and the explicit presentation of relationships among them, thereby contributing to improved learning quality and stronger feedback.

Item 15 recorded an agreement rate of 62%. It indicates that the visual-representation strategy helps in preparing summaries of lessons, reflecting the use of this approach by a considerable number of teachers to organize and simplify instructional content and to present key ideas in a concise and clear manner.

Items 17 and 23 each recorded an agreement rate of 58%. Teachers reported that visual representations help learners distinguish between similar concepts and information and facilitate the review of scientific content in preparation for examinations. These findings confirm their role in organizing knowledge, highlighting differences and relationships among concepts, and providing visual summaries that support rapid review and effective comprehension.

For Item 22, 58% of participants selected “to some extent,” compared with 42% who selected “yes.” This suggests that asking learners to prepare summaries using visual representations is still practiced at a moderate level, possibly because of differences in lesson content, limited class time, and variation in learners’ ability to produce accurate visual representations.

Finally, Item 19 recorded the lowest level of agreement: 38% selected “yes,” 43% selected “to some extent,” and 19% selected “no.” This indicates that the use of visual representations to highlight relationships among concepts and main ideas still requires greater implementation, despite being a fundamental component of effective visual representation, particularly through the use of linking words or connectors that clarify the nature of relationships among concepts.

Based on the foregoing, the results of the second dimension confirm that visual knowledge representations effectively contribute to summarizing the content of Natural and Life Sciences by organizing information, connecting knowledge, facilitating review, developing thinking, and improving academic achievement. These findings support the second sub-hypothesis and further reinforce the general hypothesis that visual knowledge representations contribute to improving the quality of teaching Natural and Life Sciences from the perspective of middle school teachers.

General Findings of the Study

This study aimed to identify the contribution of visual knowledge representations to the teaching of Natural and Life Sciences from the perspective of middle school teachers. Analysis of the participants’ responses yielded the following principal findings:

- Visual knowledge representations play an effective role in clarifying scientific concepts and information by organizing lesson elements logically, simplifying content, highlighting relationships among concepts, and connecting prior knowledge with new knowledge, thereby improving learners’ understanding of scientific content.
- Visual knowledge representations support the organization and summarization of scientific content. They help teachers prepare organized and clear summaries, enable learners to review lessons more effectively, retain information for longer periods, and develop analysis and synthesis skills, while also improving learning among low-achieving students.
- The use of visual representations enhances classroom interaction, attracts learners’ attention, and enables teachers to assess learners’ understanding of scientific concepts while taking individual differences into account.
- At the same time, the use of visual representations may face difficulties related to the time required to prepare and implement them during lessons, in addition to variation in teachers’ experience in designing and employing them systematically.

Overall, the findings supported both sub-hypotheses and confirmed that visual knowledge representations constitute an effective educational approach for improving the teaching of Natural and Life Sciences by clarifying scientific concepts and organizing and summarizing content, thereby enhancing the quality of the teaching-learning process from the perspective of middle school teachers.

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