ORIGINAL ARTICLE

Alternative Assessment and Evaluation in Science Education: Mind Maps and Concept Maps

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***Abstract**: In this study, concept maps and mind maps, which are alternative assessment and evaluation tools used in science education, were examined. The study aimed to quantitatively evaluate the concept maps and mind maps prepared by pre-service science teachers dealing with the concept of atoms. Thus, it was aimed to describe the concept of atom in the minds of pre-service teachers with different assessment tools. A case study approach was used in the study, which is one of the quantitative research designs. The study group consisted of 15 pre-service teachers teaching science in the fourth grade. Criterion sampling method was used in the study. Attention was paid to ensure that the participating pre-service teachers had undertaken all the relevant courses regarding the subject of atoms. The concept maps and mind maps created by the participants were used to describe their cognitive structures about the atom concept. The concept maps and mind maps created by the pre-service teachers were examined using quantitative analysis. It was concluded that the scores obtained by the pre-service teachers from both the alternative assessment and evaluation tools were close to their total mean scores. It was determined that the pre-service teachers could not advance as the structure grew in both concept maps and mind maps, and they had difficulties in establishing relationships between levels and hierarchies.*

Science Insights Education Frontiers 2024; 22(2):3583-3596
DOI: 10.15354/sief.24.or587

How to Cite: Eryilmaz Muştu, Ö. (2024). Alternative assessment and evaluation in science education: Mind maps and concept maps. Science Insights Education Frontiers, 22(2):3583-3596.

***Keywords:** Alternative Evaluation, Atom, Concept Map, Mind Map, Physics Education*

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***Conflict of Interests**: None*

***AI Declaration**: The authors affirm that artificial intelligence did not contribute to the process of preparing the work.*

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Introduction

WITH the radical changes introduced to the science and technology curriculum in recent years, the constructivist approach has become popular in teaching processes. In this approach, assessment and evaluation are as important as planning and implementing the learning and teaching process. With the constructivist approach, the classical approaches that focus on evaluating how much information is retained started to be replaced by alternative assessment and evaluation approaches that examine the change in students' conceptual understanding. The assessment and evaluation philosophy of the science curriculum is also based on the fact that each individual is different from another. Therefore, students' assessment and evaluation cannot be expected to take place in a standard structure suitable for everyone (Ministry of National Education [MoNE], 2018). In the alternative assessment process, students participate in the procedure of "what is taught, how it is taught and how it is evaluated" (Kreisman, Knoll, & Melchior, 1995, p. 114). Assessment and evaluation should be done as part of the teaching process, not only at the end, but throughout the learning process. Alternative assessment and evaluation techniques that focus on the learning process require the use of a greater number of, and more diverse, assessment tools or methods than the traditional approach (Gelbal & Kelecioğlu, 2007). Traditional assessment and evaluation techniques try to assess information in a limited period of time. These techniques do not give students the opportunity to perceive their own success and determine their shortcomings. These techniques do not provide enough information about the learning scheme that students create in their minds (Mumme, 1990; Shepard, 1989). Traditional approaches assess basic knowledge and skills, but measuring higher-level cognitive skills is lacking in it (Ryan, 1998; Shepard, 1989). Alternative assessment tools try to reveal not just how much students know, but what they know and what their shortcomings are. Answers given by students in these assessment tools can be evaluated in-depth. For this reason, student responses can be examined in a broader sense and analyzed from different dimensions in these assessment tools (Eroğlu & Kelecioğlu, 2011). The purpose of the evaluation created with alternative assessment and evaluation tools is not only for grading students' academic success or their group work performance. It also aims to demonstrate the progress students have made in different stages as well as the shortcomings they are expected to rectify. Therefore, alternative assessment and evaluation tools provide an opportunity to evaluate both the learning process and the product obtained as a result of the process (Eroğlu & Kelecioğlu, 2011; Okur & Azar, 2011; Yıldız & Uyanık, 2004). Alternative assessment and evaluation comprise all assessments other than conventional assessment, including multiple-choice tests with a single correct answer (Bahar, 2001). Alternative assessment and eval-

uation, also called complementary assessment and evaluation, are student-centered. Since these assessment tools take into account different dimensions such as process, performance and product, they are evaluated with a special scoring key (Bahar et al. 2010). Concept maps and mind maps are among the techniques used as alternative assessment and evaluation tools.

According to Ausebel (1968), meaningful learning only takes place when new knowledge can be associated with existing knowledge in the student's mind. Based on Ausubel's meaningful learning theory, Novak developed concept maps (Willerman & MacHarg, 1991). Concept maps are visual education tools that make use of key concepts and associate these concepts with each other using propositions (Novak, 1991). Like a graph, it shows how students integrate the key concept and other related concepts in their minds (Novak & Gowin, 1984). Students make use of the concept mapping technique to make associations by ranking the relationships between concepts in a certain order and hierarchy. By examining these relationships, information about student'' cognitive structures can be obtained (Briscoe & LaMaster, 1991). Many studies employed concept maps as an assessment tool in order to determine the cognitive structure of students (Kaya, 2003; Kılıç & Sağlam, 2004; Kinchin, Hay, & Adams, 2000; McClure & Bell, 1990; McClure et al., 1999; Novak 1990; Novak & Gowin, 1984; Ünlü, İngeç, & Taşar, 2006; İlgeç, 2008; Wandersee, 1990; Williams, 1998).

Mind maps, developed by Tony Buzan, are a visual representation of concepts related to the main concept (Kortelainen & Vanhala, 2004; Mueller, Johnston, & Bligh, 2002). The mind mapping method can be used to visualize the information learned from different sources with the help of key concepts (Farrand et al., 2002). Therefore, mind maps provide a visual way for remembering and organizing information (Holland, Holland, & Davies, 2003). While preparing a mind map, arms are drawn from the centre of the map to the outside. Colors and visual images are used to emphasize the relationships between concepts. Pictures, diagrams and words can be used collectively in mind maps to express concepts and the relationships between them (Warwick & Kershner, 2006). Mind maps can be used to summarize information about a topic or organize it through associations (Kortelainen & Vanhala, 2004). Mind maps, like concept maps, are also used as an assessment and evaluation tool to determine students' cognitive structures (Akinoğlu & Yaşar, 2007; Aslan & Gündüz, 2019; Bütüner & Gür, 2008; Evrekli, 2010; Gömleksiz & Fidan 2013; Yaşar, 2006).

While classical assessment and evaluation tools give information only about how much information is retained by the student, alternative assessment tools show students' level of knowledge, lack of knowledge, relationships between concepts and any misconceptions they may have, as well (Bahar, 2003). Since creating a concept map requires students to define the relationships between concepts, the mapping process is 'a learning experi-

ence on its own' (Jacobs−Lawson & Hershey, 2002). Concept maps provide a photograph of how the basic concepts in a field are organized and structured in the mind of the individual. Similarly, mind maps are a technique that can express the information, thoughts and concepts in the mental structure of the individual visually (Evrekli et al., 2010). Like concept maps, mind maps show all the concepts related to a subject or concept as well as the relationships between them. The image of science concepts in the mind of a pre-service science teacher is of great importance for the correct transfer of the subjects to the students when they start their career. Every pre-service science teacher should learn science concepts fully and be able to correctly express the relationships between concepts in their minds. For this reason, the cognitive structures of pre-service teachers related to basic concepts should be determined in the process of science teaching in higher education institutions. Alternative assessment and evaluation tools should be included in this process. The present study aims to use concept maps and mind maps as assessment and evaluation tools in science education. For this purpose, concept maps and mind maps prepared by pre-service science teachers about a concept were examined. The atom concept, which is one of the basic concepts of both physics and chemistry, was chosen as the main concept in the study. In addition to being an interdisciplinary concept, the atom concept is frequently used in daily life. Therefore, it is important to know how pre-service teachers organize the atom concept in their minds. The study was conducted to quantitatively evaluate the concept maps and mind maps pre-service science teachers prepared related to the atom concept and describe the atom concept in their minds using different assessment tools. In the study, it was examined whether pre-service science teacher knowledge about the concept of atom changes when measured with different assessment and measurement tools. Based on this, the problem of the research is;

Can different alternative assessment and evaluation tools be used to determine how pre-service science teacher structure information about the concept of atom in their minds? It was determined as. Accordingly, answers to two sub-problems were sought in the study:

- What are the scores of pre-service science teacher when they evaluate their knowledge about the concept of atom with a mind map?
- What are the scores of pre-service science teacher when they evaluate their knowledge about the concept of atom with a concept map?

Methods

Design

Case study method, one of the quantitative research methods, was used in this study to determine the cognitive structures of pre-service science teach-

ers about the subject of atoms using concept maps and mind maps. In the case study method, the aim is to investigate the detailed results of a particular situation by examining it in-depth. Case studies are a way of looking at what is actually happening in the environment, collecting data, analyzing data in a systematic way and presenting results. The resulting product is the precise understanding of why the event in question has occurred in that way and what to focus on in more detail for future research (Aytaçlı, 2012; Davey, 1991). This method was used in the present study in order to determine the cognitive structures of the pre-service science teachers about the subject of atoms using different assessment tools.

Study Group

The study was carried out with the participation of 15 pre-service teachers who were coaching the fourth grade of a science teaching department at a state university. Criterion sampling method, one of the purposeful sampling methods, was used for forming the study group. Purposeful sampling makes it possible to select appropriate situations depending on the purpose of the study for in-depth research (Büyüköztürk et al., 2016). Criterion sampling consists of creating sampling units in line with a set of criteria determined by the researcher in advance (Baş & Akturan, 2017). While determining the study group, attention was paid to ensure that the pre-service teachers participating in the study had taken all physics and chemistry-related courses dealing with the subject of atoms in the previous years and they would normally graduate at the end of the fourth grade. Before proceeding with the study, the participants were informed about the subject and process of the same. In addition, permission was obtained from the students to use the concept maps and mind maps they prepared as research documents.

Data Collection Tools and Implementation

The data collection tools used in the study were the concept maps and mind maps prepared by the pre-service teachers. First, the pre-service teachers were informed about the two types of maps. Then, a concept map preparation activity was carried out with the pre-service teachers. Finally, the pre-service teachers were grouped and each group was asked to prepare a concept map related to physics. Similarly, a mind map preparation activity was conducted with the pre-service teachers. Then, the pre-service teachers were asked to prepare a mind map related to physics by assigning them groups. After it was seen that the pre-service teachers could easily create concept and mind map preparation on a new subject, they were asked to create their own concept maps and mind maps related to the subject of atoms. The concept

maps and mind maps created by the pre-service teachers were examined one by one to provide data for the study.

Analysis of the Data

The data collected with the help of concept maps and mind maps were analyzed using quantitative data analysis methods in order to highlight and compare factors such as the number of concepts and links. Structural scoring method was used in the analysis of concept maps prepared by the pre-service teachers. Structural scoring method was defined by Novak and Gowin (1984) and adapted from McClure, Sonak, and Suen (1999). In this scoring method, concept maps are scored based on the number of hierarchical levels, cross links, connections and examples pertaining to them. Every relationship established between the two concepts in a concept map is a proposition. Hierarchical levels are the structures representing the relationships between concepts in the lower and upper levels. Cross links are the relationships established between the concepts at different hierarchical levels. The structural scoring system, adapted by McClure, Sonak, and Suen (1999) and used to evaluate the concept maps in the present study, is shown in **Figure 1**.

The scoring rubric developed by D'Antoni, Zipp and Olson (2009) and adapted into Turkish by Evrekli, İnel and Balım (2010) was used to examine the mind maps prepared by the pre-service teachers. An example of the scoring rubric used in the study is shown in **Figure 2**.

Results

In this section, the findings related to the scores the students obtained from the mind maps and concept maps were examined. The students' scores from the mind maps they created based on the scoring rubric were examined and given in **Table 1**.

When **Table 1** was examined, it was found that the students received points between 30 and 114 from their mind maps and their mean score was 78.07. It was noted that majority of the students scored above the mean score. When the mind maps were examined one by one, it was determined that the students failed to establish cross links and relationships in the mapping process and did not include examples, pictures and symbols at the levels of the mind maps. In addition, when the mind maps were examined one by one, it was seen that the students mostly used the second level concepts, the number of concepts decreased at the third level and they could progress to higher levels. As seen in **Table 1**, some students used wrong concepts while creating map levels. For example, Student No. 3 used the right concepts in the first and second levels of his/her mind map, whereas out of the ten concepts s/he used in the third level, nine were correct and one was wrong.

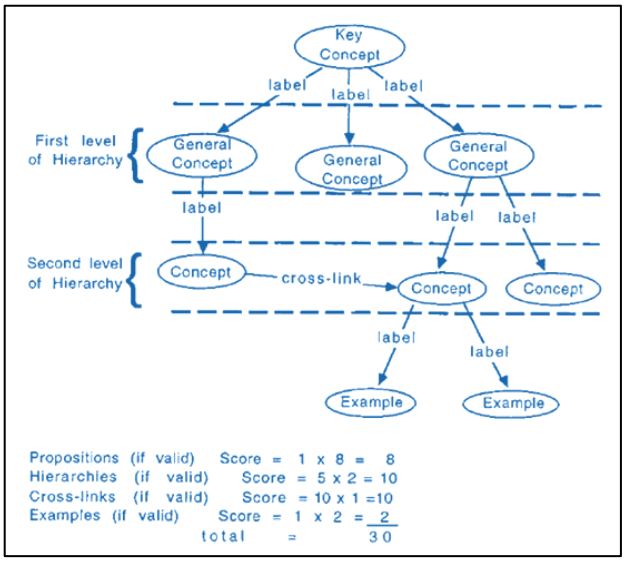

Figure 1. Instructions for the Structural Scoring Method (McClure et al., 1999).

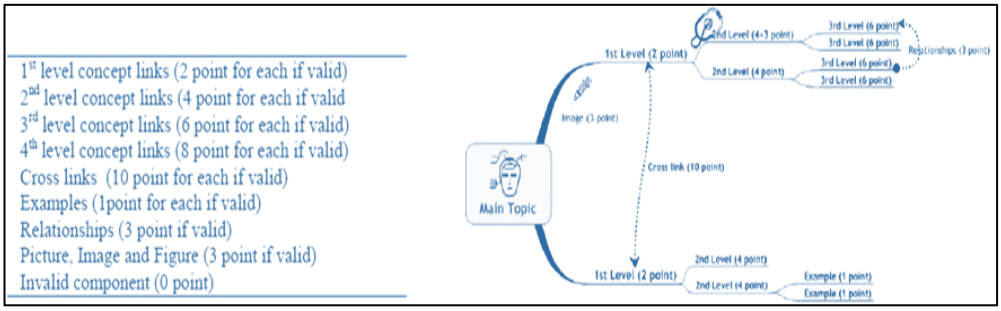

Figure 2. An Example about Scoring Mind Maps (in Mind Manager Program).

The concept maps created by the students were examined and scored one by one according to the structural scoring system, and these scores are given in **Table 2**.

When **Table 2** was examined, it was determined that the scores the students obtained structurally from the concept maps varied between 8 and 43 and the mean score was 22.07. In addition, it was seen from the Table that six students scored above the average and majority of the students received scores close to the average. When the concept maps were examined one by one in **Table 1**, it was determined that the students were able to write a total of 295 propositions, but they could not express the relationships between concepts correctly, and 146 of the propositions were wrong. When the con-

Table 1. The Scores the Students Obtained from Their Mind Maps.

	Concept Links			Cross Links	Examples	Relationships	Picture Symbol	Total Score
Student Number	**1st Level**	**2nd Level**	**3rd Level**					
	C/W*	**C/W***	**C/W***	**C/W***	**C/W***	**C/W***	**C/W***	**C/W***
1	3	12	6	0	0	0	6	108
2	4	8/3	2/6	0	0	0	0	52
3	3	12	9/1	0	0	0	0	108
4	3	15	3	0	0	0	0	84
5	4	15	4	0	0	0	0	92
6	3	13/3	4	0	0	0	0	82
7	4	16	2	0	0	0	0	84
8	3/1	6/2	0	0	0	0	0	30
9	4	19	5	0	0	0	0	114
10	4	13	0	0	0	0	0	60
11	4	8/3	0	0	0	0	0	40
12	4	11	0	0	0	0	0	52
13	4	16	2	0	0	0	0	84
14	4	11	8	0	0	0	0	100
15	3	12	2/1	0	0	0	5/1	81
Mean Score								78.07

**C/W: Correct /Wrong*

Table 2. The Scores the Students Obtained from Their Concept Maps.

Student Number	Proposition		Hierarchy	Cross Link	Example	Total Score
	Correct	**Wrong**				
1	9	14	3	0	0	24
2	5	16	2	0	0	15
3	9	9	2	0	0	19
4	8	14	2	0	0	18
5	16	6	2	0	0	26
6	8	14	2	0	0	18
7	6	22	2	0	0	16
8	9	1	2	0	0	19
9	13	10	3	0	0	28
10	9	12	2	0	0	19
11	8	3	o	3	0	43
12	17	4	2	0	0	27
13	10	12	2	0	0	20
14	16	8	3	0	0	31
15	3	4	1	0	0	8
Total	146	149	31	3	0	331
Mean	9.73	9.93	2.07	0.2	0	22.07

cept maps of the students were evaluated one by one, it was determined that they could not progress further than the 3rd hierarchy. In addition, it was seen in **Table 2** that the students could not write examples and cross links on their maps.

Conclusion

In this study, the concept maps and mind maps prepared by pre-service science teachers were quantitatively assessed in an effort to describe the atom concept in their minds using different assessment tools. As a result of the study, when the mind maps created by the pre-service teachers were examined structurally, it was seen that most of their total scores were above the average. However, it was determined that as the level of mind maps of the pre-service teachers increased, the number of concepts they used decreased. In addition, it was concluded that the pre-service teachers were not successful in providing examples in their mind maps and drawing figures such as pictures and symbols. In the mapping process, the pre-service teachers did not include cross links and relationships between levels.

When the concept maps created by the pre-service teachers were examined structurally, it was determined that their scores were generally close to the average score. It was determined that the number of correct and wrong propositions of the pre-service teachers were also approximate. In addition, it was observed that the pre-service teachers could write many propositions in the 2nd level of hierarchy in their concept maps. The pre-service teachers did not include in their maps cross links between hierarchies and concepts as examples.

In this study, cognitive structures of the pre-service teachers related to the atom concept were assessed using mind maps and concept maps. Based on the tables prepared using the concept maps and mind maps (**Tables 1 and 2**), it was clearly seen whether the relationships that the pre-service teachers established and the propositions they wrote about the concepts were wrong or correct. The wrong or irrelevant concepts of the pre-service teachers could easily be determined in this way and their shortcomings could be identified. The cognitive structures of the pre-service teachers were determined. In addition, final grades of the pre-service teachers were also calculated as a result of the quantitative evaluation. It was concluded that the scores the pre-service teachers got from both alternative assessment and evaluation tools were close to the total average scores. It was observed that the pre-service teachers failed to make progress as the structure of both concept maps and mind maps increased, and they had difficulty in establishing relationships between levels and hierarchies.

Discussion

Concept maps and mind maps are structures that visualize the concepts in students' minds on a particular subject. They facilitate the way relationships between concepts and ideas are organized. It has a visual effect that achieves this in simple terms. With these features, they enable students to express what they have learned clearly, analyze and synthesize their ideas and allow new concepts to be understood quickly and easily (Romero et al., 2017). In this study, when the concept maps and mind maps the pre-service teachers prepared about the subject of atom were evaluated, it was determined that the pre-service teachers could write enough concepts. It was found that the concepts that the pre-service teachers used in their mind maps were generally correct, but they could not correctly place many relationships among the concepts in the concept maps. This result shows that the concepts existed in the minds of the pre-service teachers, but that they were unable to establish relationships between them. This implies that the majority of the participants had knowledge about the atom concept, but had difficulty in creating a concept map. Another reason for this situation may be the fact that the rules for writing propositions for concept maps do not comply with the spelling rules of the Turkish language. This finding is similar to what Ünlü, Kandil and Taşar (2006) reported. In addition, another reason for this shortcoming of the pre-service teachers may be their lack of knowledge about the preparation of concept maps and mind maps. Different studies reported that before the use of mind and concept maps in the learning process, students should be trained for a long time on the creation of visual tools (Evrekli et al., 2010).

Scientific knowledge should be considered as an interconnected and interrelated information network. Students should associate each new topic with existing knowledge and be encouraged to think that way. For this reason, a method which sheds light on the cognitive structure of students facilitates the detection of erroneous concepts and measures meaningful learning to this end is extremely important for teachers (Bahar et al., 2002). There was a decrease in the number of concepts that the pre-service teachers used in their concept maps and mind maps as they progressed to higher levels. It was determined that the pre-service teachers were successful in associating the basic characteristics of the atom concept with each other, but they had difficulties in establishing relationships and writing propositions as their mind maps and concept maps grew. This situation can signify that the pre-service teachers were unable to make in-depth analyses of knowledge as they learned through memorization. In addition, their inability to establish relationships between concepts implies that they failed to engage in meaningful learning. The most important feature of an assessment and evaluation tool is that it can reveal the wrong concepts, lack of information and misconceptions in the cognitive structure. This cannot be done with classical assess-

ment and evaluation tools. Alternative assessment and evaluation approaches that allow the determination of individuals' cognitive structures should be included in the teaching process.

This study was conducted with a small sample. It is recommended that researchers who will conduct parallel studies first use a sample size of more than 30. Based on the findings of the present study, it is suggested that researchers should examine the cognitive structures of students both quantitatively and qualitatively using different methods of assessment and evaluation. Examination of the evaluation process in an in-depth manner by using observation or interview methods regarding their ability to prepare assessment tools is also recommended.

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Received: January 04, 2024
Revised: January 16, 2024
Accepted: February 08, 2024