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Can elementary students gather information from concept maps?

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In this study, we investigated whether concept maps were used as often and as effectively in elementary science and technology classrooms as recommended by the National Ministry of Education (MEB) in the new curricula in Turkey. In the new elementary science and technology curricula, the MEB provides a general concept map for each unit. We used concept maps provided for the Light and Sound units for fourth, fifth, and sixth grades as content to determine whether students were able to use concept maps to gather information from them. Our analyses showed that most of the students did not use the concept maps to answer the questions. Rather they used their own knowledge and cognitive structures about light and sound to answer the questions. Therefore, we concluded that students do not know how to read the concept maps and gather knowledge from them. Also, we ran an Analysis of Variance (ANOVA) test to explore whether grade level has an effect on students' performance in reading the concept maps and gathering information from them. We found that grade level has a significant effect on students' performance in using concept maps.

Keywords: concept maps, gathering knowledge, elementary science and technology

Introduction

An education system needs to be dynamic and open to innovations because of advancements in educational technologies, methods of education, and curricular content. One of the main goals of education is students' achievement, and the most important indicator for achievement is students' construction of meaningful knowledge. Research on education verifies that meaningful learning takes place when students' pre-existing cognitive structures acquire meaning (Johnson & Lawson, 1998; Novak, 1990). With this perception, mediating activities that connect prior knowledge to targeted knowledge can increase the permanence and quality of learning. Gagnon and Collay (2001) listed the six elements of learning in constructivist classrooms: situation, grouping, bridge, questions, exhibit and reflections. For them, “bridge” means connecting prior knowledge to new (targeted) knowledge. Thus bridges should be carefully planned and documented (Gagnon & Collay, 2001). Similarly, Roth, Bowen, and McGinn, (1999) showed that visual representations help the integration of new knowledge with prior knowledge and improve problem-solving skills. Concept maps, which could certainly be classified as a visual instructional tool, can be considered as a mediating tool or bridge between prior knowledge and targeted knowledge. In fact, the literature suggests that concept mapping is one of the most effective teaching tools to support meaningful learning especially in science education (e.g. Ausubel, 1968; Novak, 1977, 2010; Novak & Gowin, 1984, etc.). Concept maps created by students reveal not only their knowledge level, but also the structure of their knowledge (Novak, 2010). By using concept maps for curriculum planning, teachers can make the curriculum transparent to students (Novak, 2010).

The Turkish National Ministry of Education (MEB) released the new elementary science and technology curricula for fourth and fifth grades in 2005 and for sixth, seventh and eighth grades in 2006. In these curricula, the use of concept maps in science instruction is highly recommended (MEB, 2005, 2006). The vision of the new elementary science curricula is stated as ‘regardless of their individual differences, to educate all students as scientifically and technologically literate’ (p. 5, MEB, 2005, 2006). The MEB makes its own definition of science and technology literacy in seven dimensions that include (a) nature of science and technology, (b) key science concepts, (c) scientific process skills, (d) the relations among science, technology, society and environment, (e) scientific and technical psychomotor skills, (f) essence of science values, and (g) attitudes and valuation regarding science (MEB, 2005, 2006). As teaching key concepts is one of the seven dimensions of science and technology literacy, the use of concept maps as an instructional tool or as an assessment tool could be valuable. As to be expected, in each unit of the elementary school science and technology curricula, an inclusive concept map is provided. By providing these concept maps, the MEB aims to guide teachers in teaching scientific concepts and their relations to each other (MEB, 2005, 2006).

The MEB adopts a constructivist teaching/learning theory as an instructional approach in the science and technology curricula and understands that knowledge cannot be directly transferred from the teacher to the student. Rather it supports the notion that students’ minds are not in blank slates, and they actively reconstruct knowledge by using their previous experiences. The MEB (2005, 2006) also provides a sample student performance evaluation form for teachers. In this form, two of the fourteen skills that are measured are related to students’ understanding of scientific concepts and their correct use of concepts. Teachers are encouraged to measure students’ correct use of concepts and their ability to relate concepts to each other.

The new science and technology curricula have been in use for four years; however, how effective their new features are is still unknown. One of the most significant innovations in the science and technology curricula is the emphasis on constructivist learning methods and concept teaching. Concept maps are recommended for use as both a teaching and assessment tool in elementary science and technology education by the MEB. Determining whether concept maps are used effectively in elementary science and technology classrooms gives us an idea about the success of implementing the new curricula as a whole. The findings also allow us to identify ways to improve the implementation of the new science and technology curricula and students’ conceptual understanding in science and technology.

Background Information

Novak and Gowin (1984) developed concept maps based on Ausubel’s ‘Learning Theory’**.** Ausubel (1968) argued that learning by rote memorization did not involve learners’ cognitive structures, and it could easily be impeded by similar memorized materials. When these materials were impeded by other memorized materials, they were found to be forgotten by the learner.

Ausubel emphasized that three factors determine the functionality and permanence of meaningful material. These are its inclusion in the cognitive structure of related pre-existing concepts, stability and clarity of these concepts, and their perceptibility from the learning task. Highlighting the importance of students' pre-existing conceptions, Novak and Gowin (1984) advanced this idea one step further and argued that instructional strategies that include the use of concept maps are more effective because using concept maps as instructional tools forces students to establish relations between the concepts that already exist in their mind and the new concepts. Strike and Posner (1992) used the term 'conceptual ecology' to label the conceptual context. 'Conceptual ecology' perfectly identifies a web of interrelated concepts instead of a single concept. Thus, constructing a full conceptual understanding has nothing to do with understanding a single concept, but rather involves comprehending and relating a web of concepts and their functions.

Concepts maps have been used as a learning-teaching tool based on the idea that they ease sensible learning (Novak & Gowin, 1984; Roth, 1994). Moreover, Hoeft et al. (2003) examined how efficiently the human mind works and how the mind organizes concepts. They found that in the process of conceptualizing knowledge, we use strategies such as symbolizing, cataloguing, structuring and visualizing. Therefore, instructional activities that include these strategies may lead to conceptualizing knowledge, although they do not assure correct conceptualization.

Boyle (1997) argued that the purpose of using concept maps should be to make learning efficient rather than to facilitate learning. This idea originates from the belief that learning occurs during the use of concepts and relating them to each other. Since the use of concept maps potentially includes strategies such as symbolizing, cataloguing, structuring and visualizing, they can help students construct their own conceptual structures of science phenomena.

Students who gather knowledge by rote memorization often lack understanding of how small pieces of knowledge connect and contribute to each other and form a meaningful conceptual picture (diSessa,1988; Ebenezer, 1992), so they cannot store this information in their long-term memory (Novak, 1993). On the other hand, conceptual mapping requires connecting pieces of knowledge to each other with meaningful relations and organizing them in a wide scale by forming a conceptual frame.

While concept maps support understanding by specifically helping students organize and enhance their knowledge visually (Hoover & Rabideau, 1995; Malone & Dekkers, 1984; Novak, 2010), they could be effective in various stages of the teaching and learning process. For example, concept maps are effective in (i) constituting concrete learning; (ii) helping students who have learning difficulties; (iii) understating complex structures as a whole; (iv) enabling teachers to monitor students' knowledge and identify those students who need more help on any given subject; (v) conciliation of meaning; and (vi) tracking students' development within the process of instruction (Anderson-Inman & Ditson, 1999).

To date, concept maps have been used for various purposes in science education. They have been used as: (a) instructional tools (e.g. Horton et al., 1993; Novak, 2010; Roth, & Roychoudhury, 1993; Willerman & Mac Harg, 1991), (b) assessment tools (e.g. Gerstner & Bogner, 2009; Ingec, 2009; Stoddart, Abrams, Gasper, & Canaday, 2000), (c) curriculum planning tools (e.g. Ambe, & Reid-Griffin, 2009; Kane & Trochim, 2007; Kinchin & Alias, 2005; Novak, 2010), (d) research tools (e.g. Nicoll, 2001; Rye, & Rubba, 1998; Van Zele, Lenaerts, & Wieme, 2004), and (e) as study or learning tools (BouJaoude & Attieh, 2008; Kim & Olaciregui, 2008; McClure, Sonak & Suen, 1999).

As indicated above, in 1997, the MEB began reforms to make constructivist philosophy the spirit of the Turkish K-12 education system. As an extension of this movement, new science and technology curricula started to be implemented in all elementary schools in 2005. The MEB, by the means of its new elementary science and technology curricula, actively encourages teachers to use concept maps. It suggests that teachers use concept maps in curricular planning, teaching, and assessment. In this study, we used the concept maps that are provided in the sound and light units for fourth, fifth and sixth grades as assessment tools to investigate whether students know how to gather information from them. We sought to learn if grade level has an effect on students' understanding of concept maps. We focused on fourth, fifth, and sixth grade students who had had respectively one, two and three years of experience with the new science and technology curricula by the time this study took place.

Method

This study was conducted in 12 randomly selected elementary schools in Afyonkarahisar, Turkey. Some of the schools were in the city center, and others were in rural areas. The sample included 287 fourth grade (female = 141, male = 146), 269 fifth grade (female = 140, male = 129), and 273 (female = 139, male = 134) sixth grade students. Approximately 10 students were chosen randomly to participate from each class in the participating schools. Students were chosen from class lists corresponding to consecutive numbers of three (e.g. 3, 6, 9, and 12).

This study is part of a larger study which uses various science units as context; however, in this study the *Light and Sound* units for fourth, fifth and sixth grade elementary science and technology curricula in particular were used as context. The MEB adopted an immersive approach to deliver targeted knowledge. Thus, in each grade sound and light are taught by using fewer concepts but the subjects get more complex and are dealt with in greater depth from the fourth grade to sixth grades (MEB, 2005, 2006). Hence, new concepts can easily be linked to prior concepts. We developed a questionnaire including five identification and fifteen content questions for each grade. The content questions for each grade were prepared according to their grade level and corresponded to the unit concept maps that are provided in the curricula by the MEB. The fifteen content questions included five fill-in-the-blanks, five true or false, and five short answer questions. These questions were prepared in such a way that they can be answered using the concept maps. The concept maps for sound and light for each grade were provided in the questionnaire as well. All students were asked to answer the content questions according to the concept maps given for each unit.

To make sure that the questions in the questionnaires were valid measures of students' understanding and use of concept maps, we had the questionnaires examined by five experts from different universities and revised the questionnaire according to their recommendations. We also conducted a pilot study to make sure that the questionnaires were age and grade appropriate. Twenty three students in each grade participated in the pilot study. We asked students questions and then interviewed them about the questions. The concept maps for the *Light and Sound* units for fourth, fifth, and sixth graders and the content questions for each unit are shown in Appendices A, B, and C respectively. Concept maps can be structured in several different ways. These may include: i) linear chains, ii) hierarchical-stage maps, and iii) spider maps (Boyle, 1997). In Appendices A, B, and C, all of the concepts related to light and sound are presented in hierarchical-stage map form, and the relations between concepts are specified as well. The students' task was to gather and transfer the information from the concept map by answering the content questions accordingly.

For example, in the first fill-in-the-blanks question for the fourth graders, students were asked to fill in the blank in the following sentence:

The sun is an example of a _______ light source. (Natural)

Students were expected to gather the relevant information from the concept map. The conceptual representation of the information that a light source can be natural and the sun is an example of a natural light source is illustrated in Figure 1. The concepts related to the question are shown in lighter solid frames and the relations between those concepts are shown in lighter dashed frames. To answer this question, students need to find the relation between the concepts of *light source* and *natural* and understand that light sources can be natural or artificial. Then students need to find the relation between the concepts of *natural* and *the sun* and understand that the sun is an example of a natural light source. Our aim was to ask students questions from the units that they had already learned. Because each school teaches the units in a different order, the tests were conducted at the end of spring semester.

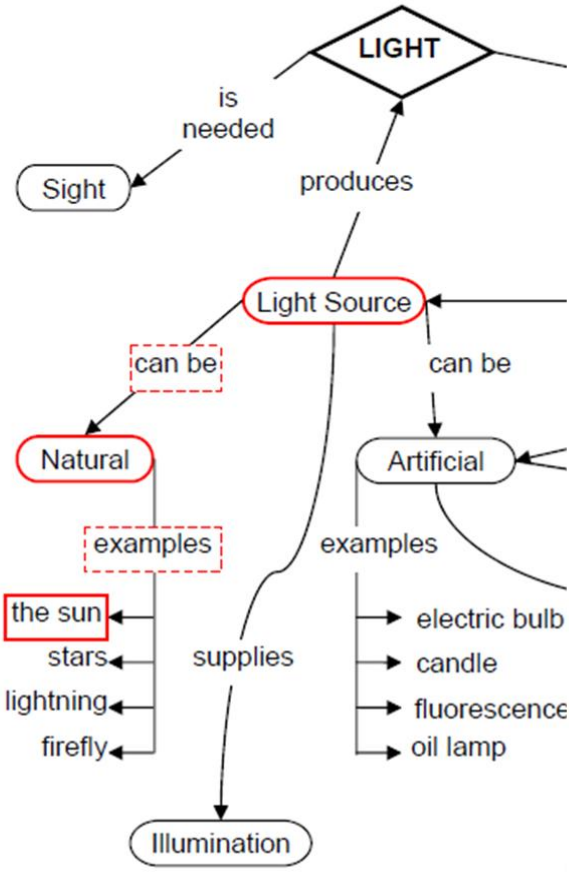

Figure 1. Conceptual representation of the information that a light source can be natural and that the sun is an example of a natural light source is the sun

The open-ended questions were scored by two of the researchers and if any of their scoring was different, they rescored those items together until they reached a consensus. After the test, students' scores were entered into Excel sheets on a computer and analyses were conducted by using MS-Excel and SPSS 17.0 programs. Means, standard deviations, frequency and percentage were calculated. To find out whether grade level had a significant effect on students' ability to read concept maps, we ran a one way Analysis of Variance (ANOVA) test. When we found a significance level we used the Least Significant Difference t test (LSD) to determine the groups that were significantly different from other groups. An alpha level of 0.05 was considered in analyses.

Results

In this section, we present students' results in answering the content questions by using the concept maps provided as their information source. The numbers of students who correctly and incorrectly answered the content questions are displayed in Figure 2. In Figure 2, the number of students who correctly answered the questions and the number of students who incorrectly answered the questions (or who did not give an answer to the questions) are displayed. Respectively, the numbers of fourth, fifth and sixth grade students who correctly or incorrectly answered the fill-in-the-blanks questions in the top graph (a), true or false questions in the middle graph (b), and short answer questions in the bottom graph (c) are shown. The graphs infer that students' performance depends on the question. In most of the questions, the majority of the students could correctly answer the question; however, in some questions the majority of the students provided incorrect answers to the questions. For example, Figure 2a shows that 91 % of fourth grade students correctly answered the first fill-in-the-blanks question whereas only 19 % of them correctly answered the second fill-in-the-blanks question. Considering the use of concept maps in answering the questions, both of those questions require the same set of skills to find the correct answers to the questions. To answer the first question, 'the Sun is an example of a _______ light source. (Natural)', as illustrated in Figure 1, students need to work out the relations between the concepts of *sun, light source,* and *natural* from the concept map shown in Appendix A.

In the second question, 'Sound source can be _______ or _______. (Natural, artificial)', students are expected to gather the related information from the concept map shown in Appendix A. The conceptual representation of the information that a sound source can be either natural or artificial is illustrated in Figure 3. The concepts related to the question are shown in lighter solid frames and the relations between these concepts are shown in lighter dashed frames. To answer this question, students need to work out the relation between the concepts of *sound*, *sound source*, *natural*, and *artificial* from the concept map and understand that sound sources can be either natural or artificial.

Similarly, in an open-ended question in the fifth grade questionnaire, students were asked: 'How is transmission of light shown?' Students were expected to use the concept map that was provided with the fifth grade *Light and Sound* unit (Appendix B). The conceptual representation of the information that the transmission of light is shown as rays is illustrated in Figure 4. The concepts related to the question are shown in lighter solid frames and the relations between these concepts are shown in lighter dashed frames. To answer this question, students need to work out the relation between the concepts of *light*, *transmission of light*, and *rays* from the concept map and understand that transmission of light is shown as rays.

Not only the aforementioned questions, but also all others in the questionnaire require the same set of skills to retrieve knowledge from the concept map; however, students' performance in different questions varied significantly. Figure 2b shows that 96.65 % of fifth grade students correctly answered the fifth true or false question, whereas just 21.35 % of fifth grade students correctly answered the first true or false question. Similarly, Figure 2c shows that 81.11 % of sixth grade students correctly answered the first short answer question whereas just 50.89 % of sixth grade students correctly answered the fifth short answer question. Since students' success in answering different questions varied greatly, it is apparent that they did not depend on the use of the concept maps provided to find the answers. Rather students used their prior knowledge and experience to answer the questions.

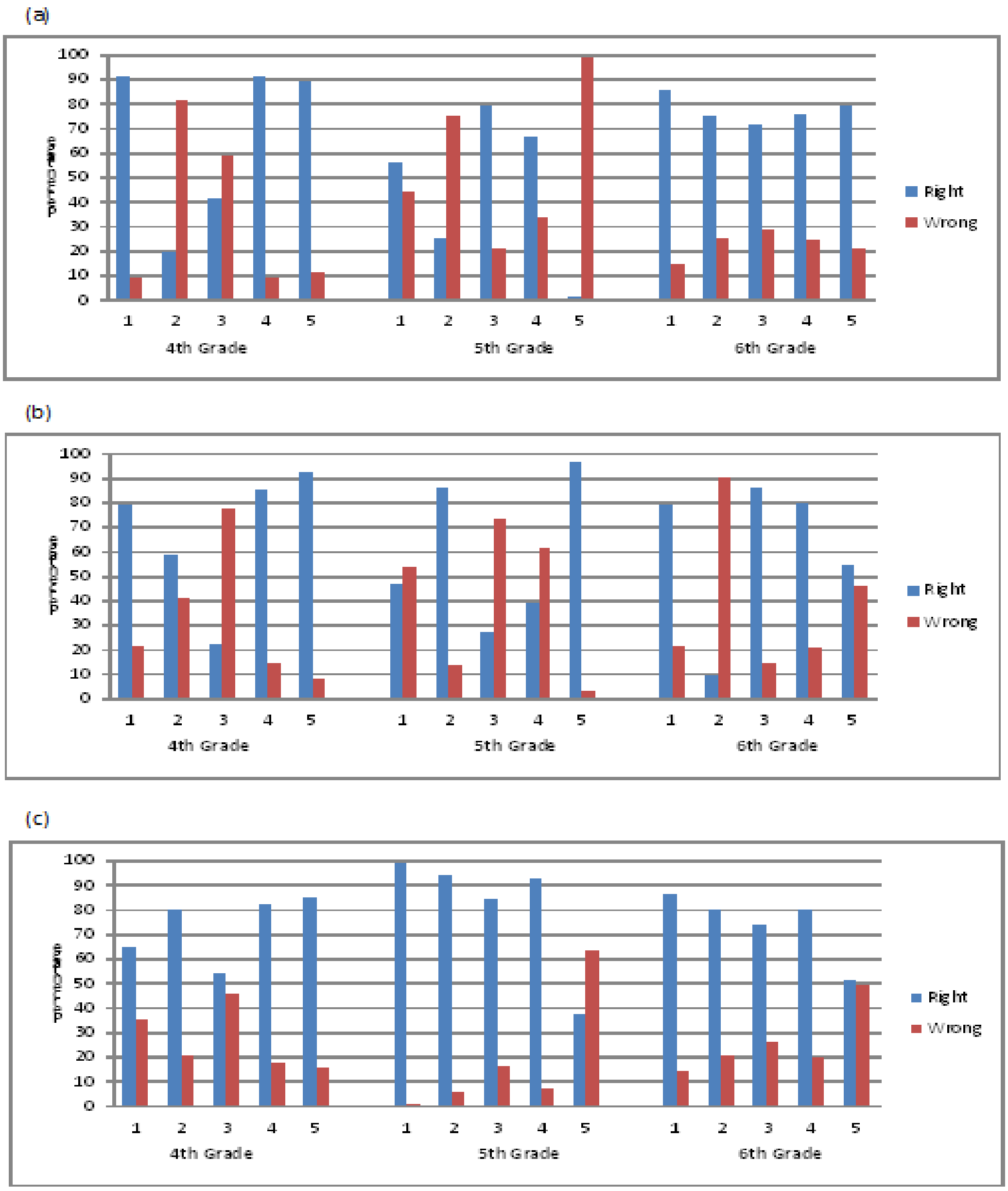

Figure 2. Percentage of students who gave right and wrong answers to (a) the fill-in-the-blanks questions, (b) the true or false questions, and (c) the open-ended questions

We also examined whether students' performance in answering the content questions differed with their grade levels. According to the ANOVA results, which are shown in Table 1, there is significant differences among students' in fourth, fifth, and sixth grade in answering the questions ($F = 8.272$, $p < 0.005$).

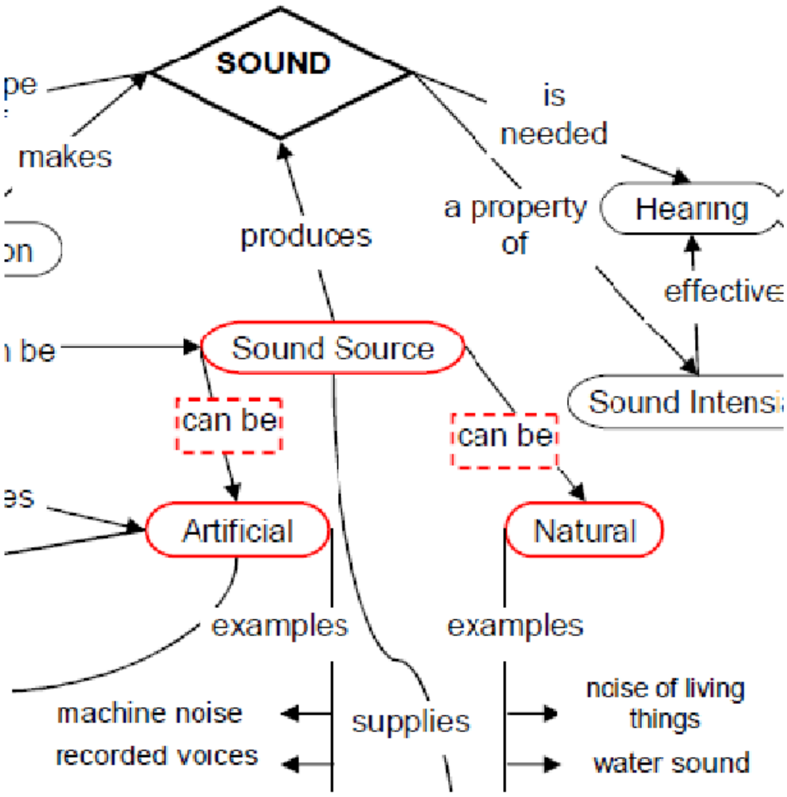

Figure 3. Conceptual representation of the information that a sound source can be either natural or artificial

Figure 5 shows students' average percentages of correct answers to the questions. There we see that the fourth and the fifth graders' average percentages of correct answers (63% and 62.6%) were fairly close to each others, while sixth graders' performance (76%) was slightly better than those of the fourth and the fifth graders. Also, the Least Significant Difference t test (LSD) results confirmed that fourth and fifth grade students' mean scores were significantly (P < 0,000) different from sixth grade students' mean scores.

Table 1. ANOVA Results for Different Grade Students' Mean Scores

	df	Sum of Squares	Mean Square	F	Sig.
Between Groups	2	55.68	10.34		
Within Groups	827	11.26	20.56	8.272	0.005
Total	829	11.25			

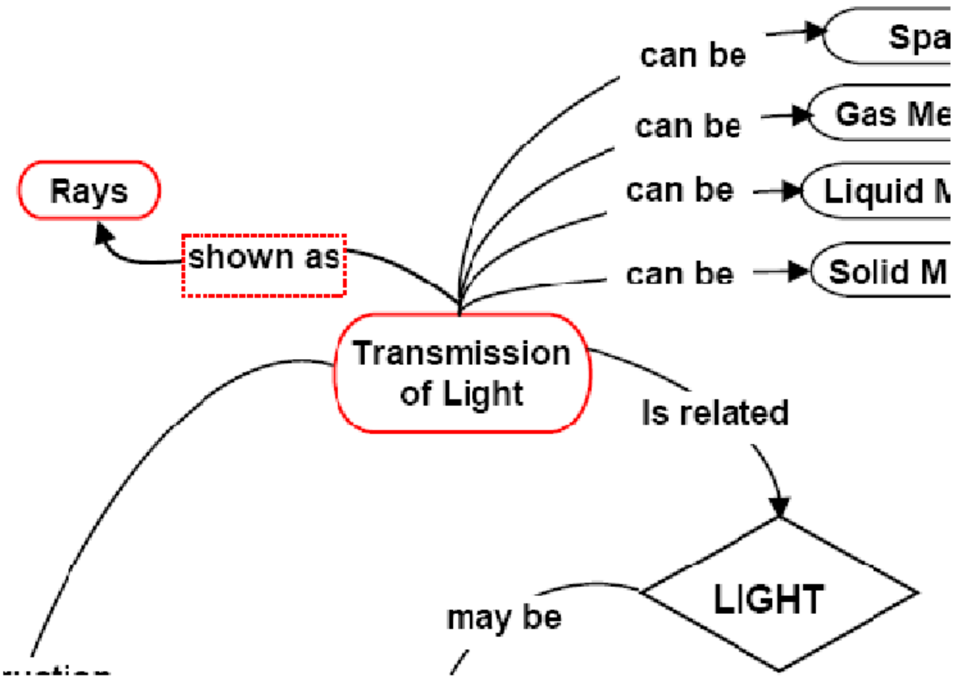

Figure 4. Conceptual representation of the information that transmission of light is shown as rays

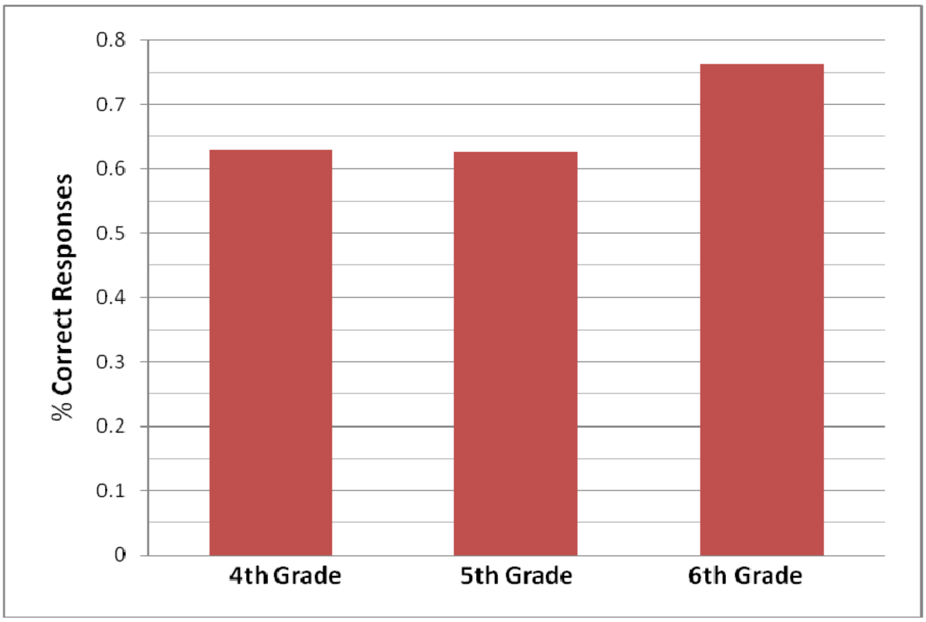

Figure 5. Fourth, fifth and sixth grade students' average percentage of correct responses to the content questions

Discussion

Our analyses showed that students' performance in finding the correct answers to different questions varied radically although answering all the questions required the same set of skills. In fact, the number of students who correctly answered a question ranged from as low as .95 % (the fifth 5th grade fill-in-the-blanks question) to as high as 96.65 % (the fifth 5th grade true or false question). To explain this, we need to make a distinction as to whether students used their prior conceptual understanding or the concept maps provided in the questionnaire to answer the questions. We believe that most of the students did not use the concept maps to answer the questions. Rather they used their own knowledge about light and sound to answer the questions.

As a matter of importance, we should seek to understand why students do not use concept maps to answer the questions. One possible answer might be that some students simply chose to ignore concept maps in favor of their own knowledge; however, they were asked to use concept maps for answering questions. Also, students should have been aware that the information they need to answer questions were given in concept maps. Another possible answer might be that the concept maps were simply not very good representations of domain-specific knowledge. Nevertheless, we have already shown how simple it was to read the concept maps provided and gather information from them. Probably, the most reasonable answer to this question is that students do not know how to read the concept maps and gather knowledge from them. The more experience students have with concept maps, the more their expertise will increase (Gerstner & Bogner, 2009). Therefore, it is fairly reasonable to think that sixth graders with three years of experience with the new science and technology curricula would be familiar with concept maps.

Students' poor performance in using concept maps for retrieving information shows that elementary science teachers do not use them either as often or as effectively as instructional or assessment tools as they should; however, elementary science teachers may have different reasons for not using them. Also, teachers may be experiencing some difficulties in adapting the features of the new science and technology curricula in their teaching. For instance, teachers need further training in creating and using concept maps in their classrooms. Therefore, they need to be engaged in training programs that can model new educational approaches such as using concept maps in the classroom (Novak & Canas, 2006). Teachers and administrators need not only training programs that teach them how to use concept maps in the classroom, but also courses that teach them the theory underlying concept mapping.

One of the limitations of the study is that, elementary science teachers' practices in the classrooms and their meta-orientations to science curricula were not investigated. We believe that data on elementary science teachers' practices in the classrooms and their meta-orientations to their curricula would undoubtedly enrich the results of the study. Schools all over Turkey are required to meet MEB curriculum standards. The samples of the study were from Afyonkarahisar, a mid-sized city in Western Turkey. In national standardized tests, students' average scores in Afyonkarahisar are very close to the national average. This makes Afyonkarahisar a good representative of the country; however, sample size may limit the generalizability of the results to the whole country.

We recommend that teacher training programs need to include courses that teach students the theory and practice of concept mapping. Also, in service training should be provided to elementary science teachers in the use of concept mapping in their classes. In this training, teachers should be introduced to different teaching strategies and tools such as concept mapping software, games with concept maps, and assessment with concept maps. In addition, teachers should beprovided a greater variety of concept maps in each unit for them to use in their teaching and assessment. Further investigation should include elementary science teachers' practices in teaching science concepts in the classrooms and their meta-orientations to the new curricula.

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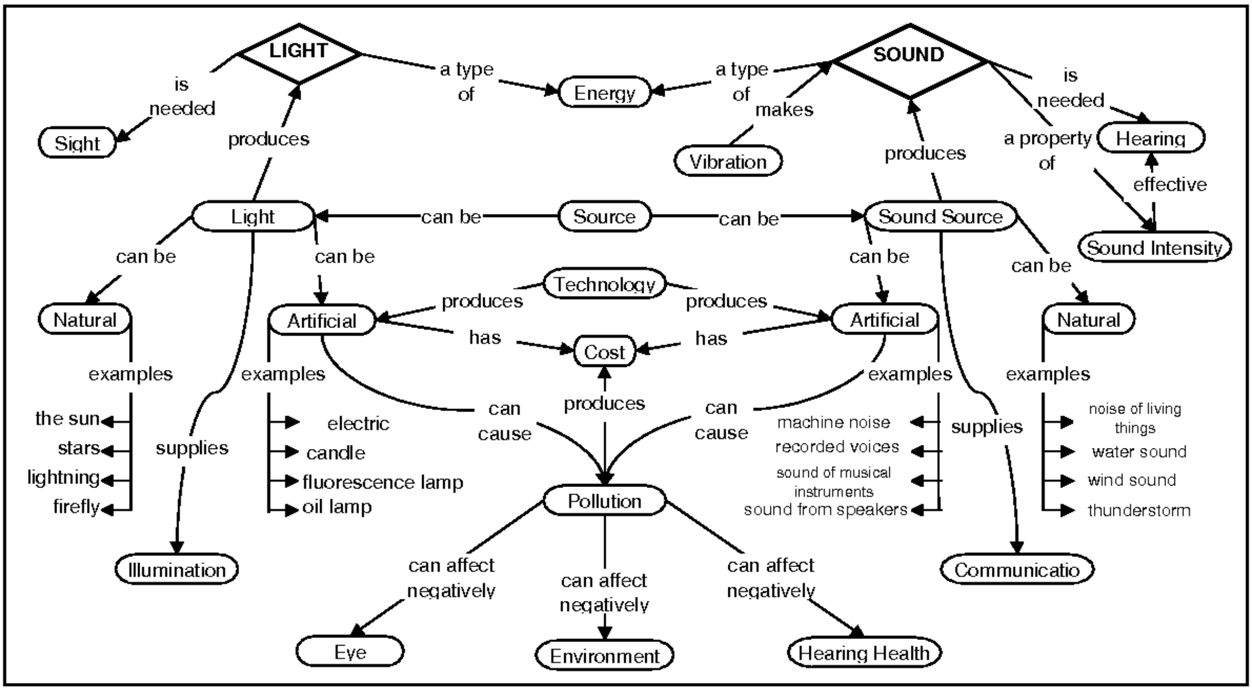
Appendix A



A. With using the concept map above, fill in the blanks with appropriate word in the questions below.

1) Sun is an example of a ________ light source. (Natural)
2) Sound source can be ________ or ________. (Natural, artificial)
3) Artificial sound sources have a ________. (Cost)
4) Florescence lamp is a _________ light source. (Artificial)
5) Light and sound are types of ________. (Energy)

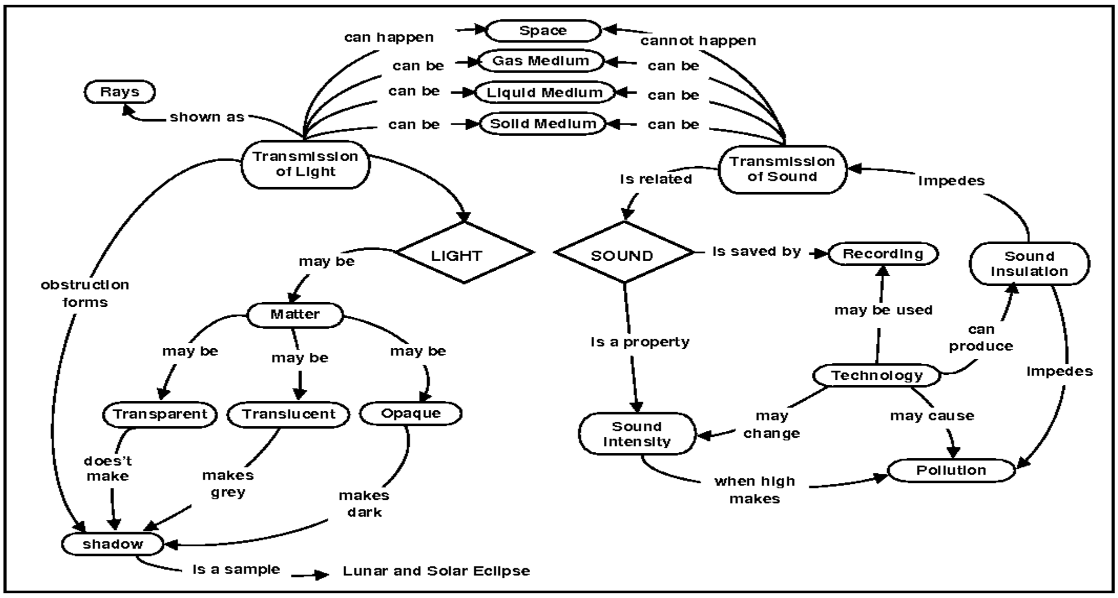
B. With using the concept map above, mark T if a statement below is True or mark F if it is false.

	T	F
1. Artificial sound and light sources pollute the environment.		
2. Illumination is made possible by artificial light sources.		
3. Technology produces natural sound and light sources.		
4. Recorded and played sound is considered as an artificial sound.		
5. Thunder is a natural sound source.		

C. Give appropriate answer to the questions below by using the concept map above.

1) Stars, lamps, candles, and fireflies are light sources. Define what a 'light source' is.
2) What are the differences between natural and artificial light sources?
3) What is light pollution? What can we do to prevent from light pollution?
4) What does make seeing possible?
5) Give (2) examples for artificial sound sources.

Appendix B



A. With using the concept map above, fill in the blanks with appropriate word in the questions below.

1. Transmission of light is about ....
2. A matter that is not transparent makes ....
3. If the intensity of sound is high, it can make ....
4. Sound can be saved by............................
5. Transmission of sound cannot happen in ....

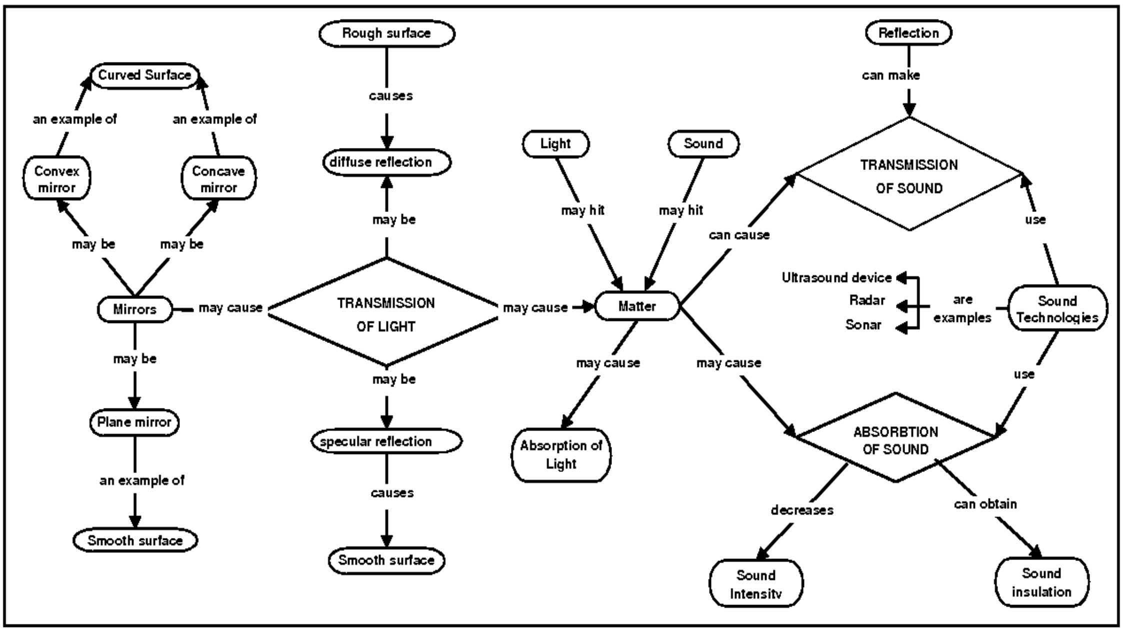
B. With using the concept map above, mark T if a statement below is True or mark F if it is false.

	T	F
1. Transmission of light is about sound.		
2. Light can only be transmitted in gas mediums.		
3. Transparent matters make shadow.		
4. Lunar and solar eclipses are examples of shadow.		
5. Insulation of sound impedes sound pollution.		

C. Give appropriate answer to the questions below by using the concept map above.

1. How is the transmission of light shown?
Answer:
2. How can matters be classified based on their transmission of light?
Answer:
3. What does change the sound intensity?
Answer:
4. In which mediums can sound be transmitted?
Answer:
5. Is there any relation between light and sound?
Answer:

Appendix C



A. With using the concept map above, fill in the blanks with appropriate word in the questions below.

1. When sound hits a hard surface and bounces back, it is called ....
2. When light hits to a rough surface, ... occurs.
3. Matter may cause sound to be .... or to be ....
4. Radar is an example of a device that uses ....
5. Absorption of sound decreases ....

B. With using the concept map above, mark T if a statement below is True or mark F if it is false.

	T	F
1. Rough surfaces may cause diffuse reflection of light .		
2. Plane mirrors have a smooth surface.		
3. Concave and conves mirrors have curved surfaces.		
4. Matter cannot cause absorption of light.		
5. Sound intensity may cause sound to be absorbed.		

C. Give appropriate answer to the questions below by using the concept map above.

1. What are the examples of the devices that uses sound technologies?
   Answer:
2. What are the types of mirrors?
   Answer:
3. How can sound insulation be obtained?
   Answer:
4. How is light reflected from a smooth surface?
   Answer:
5. How may light be reflected when it hits to matter?
   Answer: