Effect of Concept Mapping on Students' Perceived Understanding of Science Concepts

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Effect of Concept Mapping on Students' Perceived Understanding of Science Concepts

Abstract
The effect of concept mapping on students' perceived understanding of science concepts was investigated. Concept maps as a tool to assess understanding, to identify misconceptions, and to correct misconceptions were also studied. The participants in the study were three eighth graders, two girls and one boy. The students created two concept maps that were quantitatively analyzed based on the links, propositions, and cross-links for understanding and misconceptions. A questionnaire was used to find out if the students had misconceptions and to determine feelings on concept mapping and helping them to understand. The research found that concept maps make it easier for the students to understand the content. Examination of the students' concept maps revealed misconceptions that were corrected.

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EFFECT OF CONCEPT MAPPING ON STUDENTS' PERCEIVED UNDERSTANDING OF SCIENCE CONCEPTS

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The effect of concept mapping on students' perceived understanding of science concepts was investigated. Concept maps as a tool to assess understanding, to identify misconceptions, and to correct misconceptions were also studied. The participants in the study were three eighth graders, two girls and one boy. The students created two concept maps that were quantitatively analyzed based on the links, propositions, and cross-links for understanding and misconceptions. A questionnaire was used to find out if the students had misconceptions and to determine feelings on concept mapping and helping them to understand. The research found that concept maps make it easier for the students to understand the content. Examination of the students' concept maps revealed misconceptions that were corrected.
Effect of Concept Mapping on Students' Perceived Understanding of Science Concepts

As a middle school science teacher in the Rochester City School District for the past three and a half years, I have learned a lot about teaching and about the students whom I teach. Regarding teaching I can say that it is good practice to teach using different approaches, whether it is implementing the theory of multiple intelligences or utilizing problem-based learning. Furthermore teachers should use a variety of assessments such as multiple-choice tests, essay prompts, and performance tasks. As for the students, I know that they all want to be successful at whatever they do, but obstacles are harder for some of them to overcome. That is why it is so important to convince the students that they can become independent learners.

One academic tool that I have introduced in my classroom to assist the students to become independent learners is a concept map. As the students begin to construct a concept map they will discover exactly how well they understand the concepts. Most students, when they are initially introduced to concept mapping, state that it is too hard, but in the end they say that the experience was challenging, fun and more worthwhile than completing a worksheet or defining vocabulary words. The students also liked the idea that there wasn’t just one correct answer for a particular concept map. The maps that they had constructed belonged to them and no one else; it was their solution to the task. As the students explained their concept maps it gave me a chance to assess their understanding of the concepts. Most of the time the students had a better understanding because they had to explain their maps. I personally feel that this process of concept mapping will empower my students. In other words, concept mapping finally gives my
students an opportunity to express what they know and brings them a step closer to becoming an independent learner.

Furthermore, as the National Science Education Standards are implemented it is key that the students understand the concepts being taught and that the students work towards achieving scientific literacy. The National Science Education standards state that even though “hands-on” activities are vital it is not all the students should experience. Likewise the students must have “minds-on” experiences (National Research Council, 1996, p. 2). In addition, the standards call for teachers to implement a variety of assessments and not rely only on traditional tests (National Research Council, 1996, p. 6). So concept mapping could help meet the standards from at least two perspectives: instruction and assessment. As New York State standards become increasingly more challenging at all levels, students will be expected to be able to do more things. It is therefore important that the students have a chance to really connect with the material. I believe that concept mapping is a vital part to helping students meet the science standards at both the state and national levels.

So what is a concept map? A concept map is a hierarchical representation of a student’s understanding of a particular concept that shows how various concepts are interrelated. The concept map contains concepts, which are usually enclosed by a circle and propositions that are labeled by a connecting line. Novak defines concept, “as a perceived regularity in events or objects, or records of events or objects, designated by a label” (?). The label for most concepts as he states is a word or even a symbol such as + or % (Novak, ?). “Propositions are statements about some object or event in the universe,
either naturally occurring or constructed. Propositions contain two or more concepts connected with other words to form a meaningful statement” (Novak, ?).

Concept maps were created as a result of a research program in which Novak et al. sought to understand changes in children’s knowledge of science. The program was based on the cognitive psychology of David Ausubel, which states that learning takes place when the learner accepts new concepts and propositions as a part of their already existing schemas (Novak, ?). In his psychology, Ausubel also makes a clear distinction between rote learning and meaningful learning. One condition of meaningful learning is that the learner has prior knowledge that is pertinent.

With this in mind, I investigated the effect of concept mapping on students’ perceived understanding of science concepts and whether or not concept maps could assess understanding? In addition, did concept mapping help to identify and to correct misconceptions (if there were any) that the students may have held on the topic? My hypothesis was that if students constructed concept maps then these students should have a better understanding of the concepts than what they had before they constructed the concept maps. These students should be able to explain the concepts well and to be able to relate the concepts to other concepts with ease.

Literature Review

Can concept maps be used to assess understanding and conceptual knowledge? Can these maps measure changes in critical-thinking abilities? Does prior knowledge and misconceptions have an effect on understanding? Researchers have found evidence that allows a response of yes to all of the previous questions. In other words, concept maps have been found to increase understanding in more than one discipline (Daley, Shaw,
Balistrieri, Glasenapp, and Piacentine, 1999) and to show changes in critical-thinking abilities (Sungur, Tekkaya, and Geban, 2001).

In previous studies it was found that concept maps can validly be used to document and explore conceptual change in biology (Williams, 1998). In 1998, Williams conducted a study that concentrated on the use of concept maps to assess conceptual knowledge. The researcher used 28 college students enrolled in either a traditional first-year calculus class or one called reform because it focused on modeling and technology. In addition, eight professors served as experts.

In the analysis, Williams focused on differences between the two groups of students, questioning whether the concept maps revealed any differences in the concept of function and lastly whether there were conceptual differences between the students and the professors. Williams noticed that both groups of students’ maps contained trivial or irrelevant concepts and propositions (1998). As the maps of the two groups were qualitatively examined, Williams found evidence that the reform group had a better understanding that functions could be used to model actual, real-life situations (1998). When the students’ maps were compared to the experts’ maps differences in conceptual knowledge were very noticeable (Williams, 1998). This study did lend credibility to the conclusion that concept maps can capture a representative sample of conceptual knowledge, even though it may not have provided evidence that concept maps can differentiate more sophisticated levels of understanding (Williams, 1998).

Daley, Shaw, Balistrieri, Glasenapp, and Piacentine examined the use of concept maps as a strategy to teach and evaluate critical thinking (1999). In addition, the researchers found out if concept maps could measure changes in students’ critical-
thinking abilities over the course of a semester and also how faculty and students evaluated the use of concept maps in nursing education (Daley et al., 1999). Over the course of the semester the participants constructed three concept maps. The participants' concept maps were scored based on the assimilation theory. When the first and final map scores were analyzed a statistically notable difference was found, which according to the researchers was indicative of the students' increase in conceptual knowledge and critical thinking (Daley et al. 1999). Regarding the feelings of the faculty, the researchers reported that the faculty thought that concept maps as a learning tool were beneficial in demonstrating the knowledge students had gained over the semester (Daley et al., 1999). The faculty stated that they could observe the development of students' thinking processes and the maps also served as a means to correct student misperceptions during postconferences (Daley et al., 1999).

Sungur, Tekkaya, and Geban (2001) found that students who were involved in activities that helped them rethink their prior knowledge and to struggle with their misconceptions (experimental group) scored higher on the Human Circulatory System Concepts test than those students instructed with no focus on students' misconceptions (control group). The use of conceptual change texts accompanied by concept mapping led to a better understanding of the human circulatory system by allowing the students to assimilate new concepts into their existing ones (Sungur et al., 2001).

Methodology

Participants

Three eighth-grade students were chosen to participate in this study, two regular education students and one inclusion student. Each student's participation in the study
depend on whether or not they would be able to stay after school as needed for data collection. Two of the students were chosen because they had a “B+” or higher average in science class, but they usually scored average on constructed-response and written exams. The other student was chosen due to the fact that she scored below average on exams and had an overall “C” average in science.

Angela is an inclusion student with a learning disability. She is goal-oriented and has made high honor roll the first two marking periods of the school year with an “A” in science both marking periods. Although she is learning disabled and a year older than her peers are, she does not let that hinder her.

Marcus is a regular education student who truly enjoys science class. He’s not only enthusiastic, but also determined to do well. So far this year he has been on the honor role once with a “B+” average in science for the first two marking periods. He participates in class and loves to construct concept maps. Both Angela and Marcus score about average (70-75%) on selected-response tests in science class.

Joyce is a mediocre student, who is two years older than her peers are. She is not as academically stable as the other two participants are; she has yet to make the honor roll this school year. She has a “C” average for the first two marking periods in science. She usually scores below a 70% on constructed-response tests. Some days she will work really hard and others she will do half the work. At times she can be withdrawn, but on the days that we construct concept maps she is energized. Joyce and Angela are in the same science class.
Background

The unit of study for this investigation was an energy unit that focused mainly on sound during the time of data collection (Appendix A). Although one of the three students was in a different class, each class was instructed using the same methods and materials. All of the classes were allotted the same amount of time to complete the concept maps. Each class is an hour and seventeen minutes long except for on Wednesdays when the classes are about seven minutes shorter.

Angela and Joyce’s class had five (excluding her) other special education students included, therefore a paraprofessional was also present in the room to assist the students. The other class does not have any special education students enrolled; therefore I didn’t have the assistance of a paraprofessional.

The students were instructed on the definition of a concept map, the research behind this strategy, and how to construct a concept map early in the school year. This allowed the students to be familiar with constructing concept maps prior to this investigation.

Instruments

Questionnaire.

Before the students began the concept mapping process as a part of data collection, each participant completed a brief questionnaire (Appendix B). The students completed the questionnaire during homebase to reduce distractions from the other students. The students’ responses to the questionnaire were discussed with them prior to debriefing so that I could have the students explain some of the responses that were a bit vague. I also checked to make sure that the students understood each question.
I used the questionnaire to find out each student’s personal definition of understanding, to find out when they know that they understand a concept, and to probe for misconceptions. The misconceptions for that particular unit of study were researched and compared with the answers that the students wrote on the questionnaire.

Student work.

Each student individually constructed two concept maps while in class with little assistance from the paraprofessional or myself. One of the two concept maps was constructed after the students were introduced to the various forms of energy and after completing a lab activity on potential and kinetic energy. Each class was provided with the same list of terms from which to construct a concept map. The students could however add as many terms to the list as they wanted to. The second map was constructed three weeks after the first map, after completing a unit on sound energy.

During class I made sure not to lead the students, for example if they asked me a question about a particular link, I made sure to redirect the question back to them. I also observed each student while constructing his or her concept map. At the end of class or my first free period I wrote down the terms each student had trouble connecting so that I could question them about it during the debriefing.

Before the debriefing process I qualitatively assessed each student’s map based on the links, cross-links, and use of propositions. In addition, I examined each map for possible misconceptions identified earlier or any new ones that may have arisen as result of the concept-mapping process.
Debriefing

The participants stayed after school two days after completing each concept map to debrief. The responses that the students wrote on their questionnaire were used to determine the context of the questions to be asked during debriefing. Each student was asked at least one question that pertained to misconceptions during the debriefing process to see if they would answer differently.

During the debriefing session each student drew their concept maps on the white board, read it, and I asked each presenter questions pertaining to his or her map, in particular to their links. The other students also questioned the student who was presenting at that time. While each student explained their maps and answered questions that were posed, I paid close attention to their facial expressions, trying to pick up when the students were pausing to think about their response. Each student was videotaped while reading and explaining various links in their maps. All of the participants were in the room while filming and debriefing the concept map on the “Forms of Energy”.

The data for the second concept map on sound energy was collected in the same manner as the first concept map with the exception that the other students were not present in the room during the filming and debriefing. This was done to minimize the chances of the presenting student being influenced by the other students’ answers during the debriefing process, like they were during the previous debriefing session.

The debriefing session was analyzed for depth of understanding based on how well the students could elaborate on how they connected certain concepts and on the examples that they came up with to explain the concepts in more detail. The videotape of the debriefing session was reviewed and key statements were partially transcribed.
Results

What effect does concept mapping have on students’ perceived understanding of science concepts? The questionnaire (Appendix B) revealed that the students equated understanding with doing well on some type of test or paraphrasing ideas on paper. Likewise, neither student reported on the questionnaire that concept mapping helped them to understand the content the most, but instead responded that hands-on activities helped most. Even though the students did not report that concept mapping helped them to understand the concepts the most, they did report that it helps in some aspect, especially when reviewing for a test. During the debriefing all of the students agreed that concept mapping is easy if you understand the terms and how they connect, but when you are asked to explain the links and to elaborate, it makes you think more, which makes it more difficult.

Regarding the effects concept mapping has on helping the students understand science concepts in more detail, Joyce replied that it helps her understand more about what she’s learning. Angela reported that it’s an easy way to remember information if you’re going to take a test (she could not elaborate exactly on how it made it easy). Marcus replied that concept mapping helps him to understand when he knows where the terms assemble at and how they are connected (the links and propositions).

Can concept maps assess understanding? Can they identify and help to correct misconceptions? The students’ concept maps varied significantly, but for the most part none of the maps contained any cross-links. Some of the propositions were trivial and incorrect in the sense that the connecting phrase did not correctly link the words.
The students’ concept maps did however, reveal whether or not they understood the concepts and did help to identify misconceptions. Based upon the proposition that Joyce (Figure C1) used to link electrical energy to work and on her response during the debriefing session it was obvious that she did not understand the scientific definition of work.

Teacher: Discuss “these things have the ability to work” link on your map.

Student: Electricity makes things work- plug the camera in, it works.

During the debriefing when asked if she could connect any other terms on the map together she connected heat and light. She stated that light produce heat. Joyce did know that other terms were connected, which revealed that she understood more than what was drawn on her concept map. To further assess understanding I asked her another question.

Teacher: Can an object possess energy, can it have potential energy and kinetic energy, like for example, this pen in my hand?

Student: Yes.

She then proceeded to demonstrate by holding the dry erase marker in the air saying that it had potential energy and as it fell it would have kinetic energy.

Teacher: So what’s potential energy?

Student: No response- only a puzzled look on her face.

This clearly demonstrated that Joyce understands to a degree since she can demonstrate it, but she still could not give a concrete definition for potential energy.

Angela’s map on the “Forms of Energy” (Figure C2) also revealed a lack of understanding of the term work as it pertains to motion and energy. Furthermore, she
could not explain the proposition on her map that read, “they all work together and goes to one thing to another”. When asked if she wanted to change anything she changed the sound energy below magnetic energy to chemical energy. She also cross-linked light energy and chemical energy. She stated that when you add heat to a candle that it can make light. This showed that like Joyce, Angela knew more that what was shown on the concept map.

Angela stated that it was much easier for her to explain certain concepts on her sound concept map (Figure C3) than it was for her to on the Forms of Energy concept map. She also replied that after she had to explain the sound map she understood it and would probably do better on a test on sound than on the forms of energy. This shows that as a result of her completing the concept map and explaining it that she felt as though she understood enough to do well on a test.

Marcus’ map on the “Forms of Energy” (Figure C4) not only included the terms given, but he added more to the list. Like the other two students he does not understand the scientific term work.

Teacher: Explain the connection between work and kinetic energy.

Student: Kinetic energy is any type of movement and that’s doing work.

Although Marcus did not have any cross-links, his map demonstrated that he understood that energy changes form. Marcus used detailed propositions compared to Angela and Joyce, which showed that he had a somewhat “deeper” understanding of the various forms of energy. I must add though, that parts of Marcus’ propositions were incorrect, which reveals that he had a partial understanding of some of the concepts. According to his map, Marcus did know that potential energy was stored in a battery, but
he didn’t quite understand that chemical energy was the type of potential energy that the battery possessed.

Teacher: Explain the chemical-battery link.

Student: Crack a battery open and chemicals come out, electrical energy is stored in the battery.

On the questionnaire when asked about whether an object can possess energy he responded no because all things don’t have energy. He continued to elaborate by stating that in order for a baseball to have energy you have to throw it. On his energy concept map however, he wrote, “potential energy is stored in the battery”. Based on this data, concept mapping can be used to correct misconceptions.

On the other hand, concept mapping can be used to identify misconceptions. I identified two misconceptions on Marcus’ sound concept map (Figure C5).

Teacher: What’s the difference between pitch and loudness?

Student: No difference.

He then added to his map on the board a link between pitch and loudness that read, “Loudness is a high pitch”. This would explain the proposition on his map that connected pitch and wave height that read, “pitch can make it have a high wave height”. From Marcus’ map I can definitely tell where he does not quite understand and where he does understand.

To summarize, concept mapping seems to make it easier for students to understand the content. Concept mapping can also assess understanding to a certain degree, identify misconceptions, and help correct any misconceptions.

Conclusion
Concept mapping has several purposes, but in this study it was used to determine the effects it had on a student’s understanding of science concepts, to examine if it could assess understanding, and to help identify and hopefully correct misconceptions.

All of the participants had an incorrect understanding of “work” mainly because they were relying on knowledge that they acquired in 7th grade science. I only reviewed the idea of work; the students did not do any activities on “work”. Angela expressed that it would probably be easier for her to do well on a test on sound probably due to the fact that more time was spent on sound energy than on the forms of energy. As for their lack of cross-links, I believe that if I would have encouraged them to include them then the students would have followed through.

One important result that was revealed due to this research, which is not surprising in this test driven society and state, is that students equate understanding with doing well on a test. Some students just aren’t good at taking multiple-choice tests, but that doesn’t mean that they do not understand the content. The students who participated in this study are prime examples of students who do not test well, but understand more than what’s attained on tests. These students need to be aware of this fact so that they do not become discouraged if they do poorly on an exam.

Concept mapping allows for students to look at the big picture, not just a segment of it. It forces them to get involved and to think about the relationships between concepts. So I would encourage all educators to have multiple assessments so that they to can discover what their students understand, but just aren’t showing due to the circumstances.
I am not saying that concept maps reveal everything a student understands because they do not. I discovered that the students would make cross-links on their maps if prompted to do so, which revealed that the students knew more about the concept than the concept map was revealing. Williams (1998) study, which concluded that concept maps could capture a representative sample of conceptual knowledge, lends support to my finding.

The students did report that concept mapping makes it easier to understand the content, but they could not explain how. I would therefore, follow up with another investigation that would delve into that issue of how concept mapping makes it easier. Teachers would also have to make time to clear up any misconceptions that may be unveiled during concept mapping. Sungur et. al (2001) found that students that had an opportunity to rethink prior knowledge and struggle with their misconceptions did better on an exam compared to those who did not.
References


That's all.
Appendix A

NYS Science Standards and Major Activities

NYS science standard Key Idea 4- Energy exists in many forms and when these forms change, energy is conserved.

Background- There are two main forms of energy, potential (stored energy) energy and kinetic energy (energy due to motion). Objects possess different forms of energy, which include mechanical, sound, light (electromagnetic), heat, electrical, magnetic, chemical, and nuclear energy. As key idea 4 states energy can be transformed, but it is never created nor destroyed (Law of conservation of energy).

Sound is a form of energy that results when matter vibrates. Sound travels in the form of a longitudinal wave. It therefore has properties of a wave such as frequency, wavelength, and amplitude. Sound has other properties such as pitch, which depends on the frequency of the wave. It also has loudness, which is related to the amplitude of the wave. Sound can be reflected (echo), absorbed, and refracted (change of speed through different media). The speed of sound depends on the type of medium and the temperature of the medium.

NYS Performance Indicator 4.1- describe the sources and identify the transformations of energy observed in everyday life.

Objective: Describe the difference between potential energy and kinetic energy.

Activity: Rolling Spheres (Students must design an experiment first)

Question to investigate: Using various inclines and spheres, what situation do you predict would cause the slider to move the farthest?
Appendix A

Activity: Using a ping pong ball and a golf ball, design an experiment that demonstrates the transfer of energy.

Activity- Energy Collage and essay
Cut out pictures from a magazine that represent at least 6 different types of energy transformations. Then write an essay in which you describe how life would be without energy.

NYS Performance Indicator 4.4- Observe and describe the properties of sound, light, magnetism, and electricity.

Questions: What's pitch?
How does the height of a column of air effect the pitch of a sound?

Activity: Bottle Tunes, Straw Horns, Rubber Band Sounds- Exploring Pitch
Appendix B

Questionnaire Form

Directions: Below are a series of questions that I would like for you to take your time to complete. Your responses will help in my research that I am conducting on concept maps and understanding. Please answer as honestly and thoroughly as you can. There are no wrong or right answers in this questionnaire.

1. How would you define the word **understanding**?

2. How do you know when you understand a particular science concept?

3. What types of things do we do in science class that help you to understand the content better?

4. Which of those things would you say helps you to understand the content the most? Why?

5. Which of those things would you say helps you to understand the content the least? Why?
Appendix B

6. What are your thoughts on concept mapping? How does it help you to understand science concepts, assuming that it does help you?

7. If we have not done something in science class that could help you understand science concepts better, what would that be?

8. Do you have trouble understanding science concepts due to your prior experiences in life and prior knowledge conflicting with new information? In other words have you known something related to science concepts to be true, but you have been told by others that it isn't?


10. Certain objects have energy and certain objects need it. Agree or disagree. Explain your answer.
Figure 1. Joyce's forms of energy
Figure 2. Angela's forms of energy

- **Energy**
  - Has two types:
    - Potential energy
    - Kinetic energy

  Potential energy:
  - Is a form of energy that is stored to be used later
    - 4 different types are:
      - Nuclear energy
      - Sound energy
      - Light energy
      - Magnetic energy

  Kinetic energy:
  - Is present in anything that is moving, which are:
    - Mechanical energy
      - And
    - Electrical energy
      - And
    - Heat energy
      - And
    - Sound energy

  They all work together and goes to one thing to another.
Figure 3. Angela’s sound concept map
Figure 4. Marcus' Forms of Energy
Figure 5. Marcus' sound energy concept map

Appendix C

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