MIDDLE SCHOOL SCIENCE TEACHERS' UNDERSTANDING OF STUDENTS' MISCONCEPTIONS OF PHOTOSYNTHESIS AND RESPIRATION

by

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CERTIFICATION OF PROJECT WORK

We, the undersigned, certify that this project entitled Middle School Science Teachers' Understanding of Students' Misconceptions of Photosynthesis and Respiration by Nicole S. Kestler, Candidate for the Degree of Master of Science in Education, Curriculum and Instruction, is acceptable in form and content and demonstrates a satisfactory knowledge of the field covered by this project.

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Abstract

Do middle school science teachers accurately identify common misconceptions that students have about photosynthesis and respiration and what do teachers do to address them? Six middle school science teachers from western NY schools were interviewed in order to discover if they knew what misconceptions their students had regarding photosynthesis and respiration and what they did to address these misconceptions. None of the teachers demonstrated a true understanding of what a misconception is. The science certified teachers knew some of their students' misconceptions in photosynthesis and respiration, but most of the non-science certified teachers did not realize their students had misconceptions in these topics. In addition, the majority of teachers did not have specific instructional strategies to address their students' misconceptions. This study has implications for the preparation of both certified science teachers and elementary teachers responsible for teaching science.

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Introduction

Teaching in general is a difficult task, but teaching science becomes more difficult because of the misconceptions students already have when entering a science classroom. “It becomes more difficult to teach students without actually addressing the misconceptions first,” stated Anu Malipatil, a school administrator (Lempinen, 2011, para. 13). A misconception refers to students’ thoughts and ideas that differ from ones accepted by scientists (Stein, Barman, & Larrabee, 2007). In an effort to gain scientific literacy for all Americans, including middle school students, there has been a growing effort to identify and overcome misconceptions.

There are a plethora of misconceptions students have in regards to science concepts which makes learning much more difficult. These misconceptions make teachers’ jobs more challenging because in order for their students to gain a true understanding of science concepts, teachers must address misconceptions first in order to change the way their students think about these science concepts. This is why it is important for teachers to know what misconceptions their students have before instruction.

Teachers not only need to recognize students’ misconceptions, but they also need to know how to address these misconceptions. If students’ thinking and understanding do not change, there is no point in knowing where they struggle. In order for teachers to address their students’ misconceptions, they first need to recognize and address their own misconceptions. During my Master’s program, I took a graduate-level Physics class for teachers that was designed to expose our misconceptions so, we could learn the correct way of thinking as well as recognize where our students struggle. Throughout the course I realized that I harbored several misconceptions, and I would need to relearn these science concepts first in order to teach them to my students. I do not want to reinforce misconceptions but rather recognize them and address them in order to promote true understanding.

My research question is, "Do middle school science teachers accurately identify common misconceptions that students have about photosynthesis and respiration and what do teachers do to address them?" Much research has been done on students' misconceptions in science, but most of the research is on concepts in physics and earth science. Research also needs to be done in the other sciences including biology (also known as Living Environment). Photosynthesis and respiration are important concepts middle school students need to understand. The New York State Intermediate Level Science standards (grades five through 8) for Living Environment mandate the specific topics and concepts that students need to learn in school. Performance indicators 5.1c and 5.1d address the issues of photosynthesis and respiration in this way:

> All organisms require energy to survive. The amount of energy needed and the method for obtaining this energy vary among cells. Some cells use oxygen to release the energy stored in food. The methods for obtaining nutrients vary among organisms. Producers, such as green plants, use light energy to make their food. Consumers, such as animals, take in energy-rich foods. (The University of the State of New York, 2009, p. 18)

These performance indicators express what students in middle school should know about photosynthesis and respiration. Unfortunately, students may struggle with these concepts and harbor misconceptions about them. Teachers need to realize this, so they can address their students' misconceptions in order to promote student learning and true understanding.

Students learn about photosynthesis and respiration at an early age, but some of them still hold on to their previous ideas and demonstrate their lack of understanding when they reach middle school. What do teachers know about their students' misconceptions in photosynthesis and respiration? Do they know that their students have misconceptions? What do teachers do to address their students' misconceptions? Education programs may help some preservice science teachers focus on student thinking and help teachers incorporate their students' current ideas into their instruction in a way that builds upon students' current concepts (Larkin, 2012). "There is a need to equip teachers with effective instructional approaches to overcome misconceptions that result in meaningful learning (Ameyaw & Sarpong, 2011, p.17). I interviewed six middle school science teachers in rural and urban school districts in western New York to discover the answers to these questions. Many research studies have been conducted about students' misconceptions in science so I was able to compare the teachers' knowledge with this previous research. I found that the teachers do not know the common misconceptions their students have in regards to photosynthesis and respiration. In general, the science certified teachers were more successful in naming misconceptions their students had compared to the non-science certified teachers. Only one of the science certified teachers used a research-based strategy to address these misconceptions. In order to identify which misconceptions a particular group of students have, teachers should be pretesting them using conceptual questions. Teachers also need to plan lessons that highlight the conceptual change model in order to help their students overcome their misconceptions. As a teacher, it is essential to understand what misconceptions are.

Literature Review

When students enter a new class, they are not blank slates waiting to be filled with new knowledge. They have many ideas already, and in science, some of these beliefs and ideas do not match up with what is scientifically correct and are therefore considered misconceptions (New York Science Teacher, 2012). "Misconceptions can be referred to as a preconceived notion or a conceptual misunderstanding" (New York Science Teacher, 2012, p.1). Many people who have misconceptions do not know their ideas are incorrect and have difficulty changing them (New York Science Teacher, 2012). In order to help students gain a true understanding of concepts in science, teachers need to find out what misconceptions students have and figure out how to address them. Students harbor several misconceptions in the life sciences including the topics of photosynthesis and respiration. Life science teachers need to understand where students' misconceptions come from so that they will be more knowledgeable in how to dispel them. They also need to be familiar with common misconceptions and make sure that they themselves have sufficient knowledge of the subject matter and do not harbor misconceptions of their own. Life science teachers also need to guide instruction in a way that exposes and addresses these misconceptions in order to overcome them. Research studies have shown that misconceptions involve conceptual ideas and need to be addressed conceptually (Gooding & Metz, 2011). By using a conceptual change teaching approach, life science teachers can help students identify and overcome their misconceptions in photosynthesis and respiration.

Origins of Students' Misconceptions

Recognizing student misconceptions is an essential component to effectively teaching science. In order to improve science education, educators must recognize how misconceptions are formed and what misconceptions students have for a particular topic. For the purpose of this thesis proposal, the topics of focus will be photosynthesis and respiration. When teachers know the origins of science misconceptions, they are better equipped to address them.

Students' thinking processes. The first step teachers need to take when addressing misconceptions is to understand how they are formed and where they come from. According to Gooding and Metz (2011), misconceptions are formed because of the way our brain stores information. When a person's brain receives new information, it stores this information by making connections to previous information (Gooding & Metz, 2011). If the new information does not fit with the old, it is reformatted to conform to the existing blueprint (Gooding & Metz, 2011). When this happens, misconceptions are unknowingly created and reinforced as the learner tries to build explanations and solve problems based on faulty reasoning (Gooding & Metz, 2011). In other words, sometimes students' current concepts are insufficient in allowing them to successfully understand new observations (Posner, Strike, Hewson, & Gertzog, 1982). When this happens, the students must replace or restructure their current concepts (Posner et al., 1982). If they do not, they will form misconceptions by trying to force new information to fit into their old concept.

How students process new information and *how* students think can indicate how successful students will be in understanding respiration concepts (Alparsian, Tekkaya, & Geban, 2003). Formal operational thinkers are more likely to understand difficult science concepts such as respiration because they can reason and process information abstractly and hypothetically (Alparslan et al., 2003). Students who use these process skills are more likely to gain a true understanding of science concepts and less likely to form misconceptions.

Even though misconceptions may be formed unknowingly, they can be fostered and advanced by different experiences. Many factors can foster and advance student misconceptions including the learners themselves (because of the way the brain stores information), media, textbooks, and teachers (Gooding & Metz, 2011).

Misconceptions from media. Barnett et al. (2006) argue that in order to effectively teach science, teachers need to be cognizant of how popular culture, especially movies, influences students' understanding of science. Hollywood studios try to blend fact with fiction in order to make a movie appear more realistic so the viewer can better relate to it (Frank, 2003). The viewer's perception of reality can become blurred and cause confusion as to what is real and what is not (Frank, 2003). Even though the general public is aware that movies are entertainment and not real, children have difficulty differentiating between the two (Frank, 2003).

Barnett et al. (2006) conducted a study at an urban/suburban middle school to determine what effect watching the movie *The Core* would have on a culturally diverse group of 8th grade students after completing an Earth Science unit on Earth's interior structure, Earth's magnetic field, earthquakes, and plate tectonics. All 82 students had the same four-week lesson plan. Three of the classes saw *The Core* at the end of the unit in class. The students were interviewed before and after the unit on the Earth with the same questions.

The results showed that students who watched *The Core* were more inclined to think that the inner core was a liquid rather than a solid. All students were unable to give a scientific explanation for the causes of the Earth's magnetic fields. This study found that students who watched *The Core* were influenced by the movie as shown in their responses. They were more inclined to explain their reasoning based on scenes from *The Core* rather than class experiences. The researchers believed the students' misunderstandings were based on the plausibility of the science in the movie, scientific authority of the main character, and memorable images that outweighed hands-on experiences in class. One of the possible reasons why the proposed scientific explanations in movies are so believable is because they are presented in an intuitive way. Film makers do not want the audience to feel confused which can have a negative impact on their profits. Students could have also thought *The Core* was based on reliable science since they watched it in class. If the teacher sanctions the movie, the students are more likely to accept it as fact. The teacher's thoughts and opinions have a lot of influence on the students' learning, so the teacher needs to make sure that any information presented in the classroom is accurate (Barnett et al., 2006).

Misconceptions from textbooks. Images in textbooks can be very misleading and cause students further confusion. I, myself, have seen textbooks that contain a diagram depicting the Earth's revolution around the sun shown at an angle which led children to believe that the Earth's revolution was severely elliptical rather than only slightly elliptical. That skewed diagram contributes to a widely believed misconception that the reason for seasons is because of the Earth's changing distance from the sun. While that particular diagram is only misleading and not actually wrong, some science textbooks contain incorrect information. John Hubisz performed a study that reviewed science textbooks and he found several errors including pictures of prisms bending light the wrong way, statements about the Statue of Liberty that say it is made of bronze instead of copper, and information about sound that says humans cannot hear below 400 hertz even though there are many piano keys that are below 400 hertz (Walton, 2002).

Some science textbooks have incorrect or misleading information in regard to photosynthesis and respiration. A study by Dikmenli, Cardak, and Oztas (2009) found that there were conceptual problems in 12 out of 15 science and technology textbooks examined that could lead to misconceptions. One textbook stated that living things have developed organs that are used for respiration (Dikmenli et al., 2009). This is not true and this statement also shows that the terminology in textbooks can be confusing. The term *respiration* is especially confusing because it is sometimes used as a reference to breathing in humans or the exchange of gases on a cellular level. There are textbooks that insinuate that photosynthesis occurs in plants by day and that respiration only occurs at night (Gooding & Metz, 2011). If this were true, plants would die. Plant cells are constantly respiring which is a vital process in all living organisms. This misconception that photosynthesis and respiration cannot occur simultaneously is common (Yenilmez & Tekkaya, 2006). Many students harbor the misconception that respiration only occurs at night when plants are not able to photosynthesize (Yenilmez & Tekkaya, 2006). Another misconception is that plants do not respire; they only photosynthesize (Yenilmez & Tekkaya, 2006).

Misconceptions can evolve whether or not the information in textbooks is incorrect or deceiving. However, it is challenging for teachers to overcome common science misconceptions when science textbooks contain deceptive or inaccurate information.

Misconceptions from teachers. Teachers, without even realizing it, sometimes have misconceptions and teach them to their students (Gooding & Metz, 2011; Stein et al., 2007). When teachers unknowingly pass their misconceptions onto students, these erroneous ideas may never be changed (Gooding & Metz, 2011). The longer students hold on to a misconception, the harder it is to change it.

Several studies have been conducted to determine what misconceptions preservice teachers and classroom teachers have in science and more specifically, photosynthesis and respiration. According to a study by Bursal (2012), at least 40% of the 55 preservice elementary teachers from an American university possessed seven of the 11 common science misconceptions including “plants get their food from the soil” (p. 50). Similarly, a study by

Cokadar (2012) found that a majority of the 152 prospective elementary teachers who were surveyed did not have a true understanding of photosynthesis and respiration concepts.

Since one of the origins of students' misconceptions in photosynthesis and respiration is teachers, it is important to discover what misconceptions teachers have in this area. Krall, Lott, and Wymer (2008) conducted a study to ascertain conceptions of elementary and middle school teachers in regards to the role of photosynthesis and respiration in an ecosystem. Participants included 76 inservice elementary and middle school teachers from rural school districts. They took a 25-question multiple choice test to gauge their understanding of life science topics. Responses were analyzed on four different tasks to assess the teachers' understanding of that topic.

In order to obtain a correct answer for the first task, one would need to understand that seed germination and plant growth have different requirements. Plants need water, nutrients from soil, and sunlight while seeds only need water since their nutrients are stored within the seed. (Some seeds need a small amount of sunlight to activate germination but not nearly the amount needed for photosynthesis). Forty-seven percent of the teachers answered the question correctly while 42% thought seeds need the same things that plants need i.e. water, nutrients from soil, and sunlight (Krall et al., 2008).

Task two showed that 65% of the participants correctly recognized the cotyledon as the source of food for germinating seeds. The incorrect answers were divided into seeds obtaining food from the soil, seeds making food through photosynthesis, and a young plant not needing food until after it begins to grow (Krall et al., 2008).

Task three asked teachers which substance trees use in the largest quantities to develop a large trunk. Only 5% of the teachers correctly identified carbon dioxide as the substance. Thirty-eight percent thought the correct answer was nutrients from the soil and 50% thought it was a combination of carbon dioxide, nutrients from the soil, and sunlight. These results suggest that teachers think other resources are responsible for a plant's biomass instead of gases (Krall et al., 2008).

The fourth task was used to assess the teachers' understanding that plants consume oxygen during respiration (like animals). Only 25% of the participants chose the correct answer which indicated that plants consume oxygen and release carbon dioxide (Krall et al., 2008). Many students and teachers harbor the misconception that plants only respire at night when actually, they are constantly respiring.

The results on these tasks show that many elementary and middle school teachers have misconceptions about photosynthesis and respiration (Krall et al., 2008). Teachers need to recognize that their students may have the same misconceptions that teachers themselves have and perhaps more or different misconceptions.

Students' Misconceptions

Students harbor many misconceptions in the sciences including biology (or life science). The topic of photosynthesis is difficult for students to understand because they have to think conceptually instead of concretely (Marmaroti & Galanopoulou, 2006). This leads to several misconceptions including the autotrophic nature of plants, energy transformations, respiration, and 'inverse respiration' (Canal, 1999; Marmaroti & Galanopoulou, 2006; Ozay & Oztas, 2003).

The autotrophic nature of plants. Marmaroti and Galanopoulou (2006) administered a questionnaire to 292 middle school students in seven different schools in Greece after the chapter on plant respiration was taught. The results of the questionnaire revealed many student misconceptions (Marmaroti & Galanopoulou, 2006). Fifty percent of students were not able to demonstrate their understanding of the autotrophic nature of plants by correctly answering the questions, “Why are plants called autotrophs?” and “Which is the origin of the plant nutrients?” (Marmaroti & Galanopoulou, 2006, p. 395). When students are able to display their knowledge of the autotrophic nature of plants, they demonstrate their ability to conceive that plants are not fed the same way as humans and animals (Marmaroti & Galanopoulou, 2006). Students do not have a good understanding of autotrophic feeding according to a study by Ozay and Oztas (2003). They administered a questionnaire to 88 Grade 9 students from a school in Turkey to assess students’ misconceptions in photosynthesis and related topics (Ozay & Oztas, 2003). In this study, they found that students do not realize that plants produce organic materials from carbon dioxide and water (Ozay & Oztas, 2003). Students do not understand why plants are called producers. About half of the ninth grade students questioned in the study by Ozay and Oztas (2003) thought that plants are called producers because they produce fruits or vegetables. Part of the reason why students have difficulty understanding these concepts is because of the multiple meanings of words. Middle school students also have difficulty understanding the chemical reactions involved in energy transformations.

Energy transformations. Only 30% of the middle school students correctly identified where photosynthesis takes place and where chlorophyll is located (Marmaroti & Galanopoulou, 2006). This shows that the majority of students do not understand the role chlorophyll has in photosynthesis. Other questions asked students about the role of the sun in photosynthesis.

Although 80% of students answered that the sun supplies plants with the energy needed for photosynthesis, 40% answered that the energy is in the form of sunlight and heat (Marmaroti & Galanopoulou, 2006). The ninth grade students also believed the sun keeps plants warm (Ozay & Oztas, 2003). Therefore, students were not able to correctly identify the type of energy needed for photosynthesis (Marmaroti & Galanopoulou, 2006). The students also demonstrated that they do not know how energy is converted during photosynthesis (Marmaroti & Galanopoulou, 2006). The wording of the question may have been misleading, but only 10% of students correctly identified that plants trap light energy to convert it to another form (Marmaroti & Galanopoulou, 2006). Seventy percent of students thought that energy is produced during photosynthesis (Marmaroti & Galanopoulou, 2006). However, one of the fundamental laws of science states that energy cannot be created (produced) or destroyed. Energy flow is a concept that is important for students to understand because it is broader and encompasses several topics in biology (Ozay & Oztas, 2003). Students also have misconceptions in regards to respiration.

Respiration. Students often are confused about the reactants and products of photosynthesis (Marmaroti & Galanopoulou, 2006). Sixty-five percent of students were not able to identify the reactants of photosynthesis (Marmaroti & Galanopoulou, 2006). The students who chose the answers that listed oxygen as one of the substances needed for photosynthesis were confusing photosynthesis with respiration (Marmaroti & Galanopoulou, 2006). Sixty-two percent of students accurately identified glucose and oxygen as the products of photosynthesis but when cross-analyzed with the previous question, only 25% of students answered correctly (Marmaroti & Galanopoulou, 2006). Some students have the misconception that green plants only photosynthesize and do not respire (Yenilmez & Tekkaya, 2006). About half of the ninth grade students thought that plant respire only at night (Ozay & Oztas, 2003). They may believe this because photosynthesis only occurs during the day and respiration is sometimes considered to be the inverse of photosynthesis because of their opposite products and reactants.

Inverse respiration. The concept of inverse respiration is the idea that plant respiration is an inverse gaseous exchange compared to animals (Canal, 1999). This idea causes students to compare plant respiration to that of an animal breathing-taking in and expelling air (Canal, 1999). Inverse respiration also overemphasizes oxygen as a product when the production of glucose is the more important product for plants (Canal, 1999).

The idea of plants breathing like animals relates back to misconceptions from teachers. A teacher's overemphasis on gaseous exchange may lead students to believe this misconception of inverse respiration (Canal, 1999). Teachers need to identify their students' misconceptions as well as their own in order to overcome misconceptions.

Overcoming Misconceptions

Once teachers have identified the origins of misconceptions and recognized their students' misconceptions as well as their own, they can help students overcome misconceptions and solidify a correct conceptual understanding. The use of a research-based instructional strategy can assist students in overcoming their misconceptions. In order to help correct students' misconceptions teachers can not merely dictate the correct answer (Gooding & Metz, 2011). Effective strategies should give students the opportunity to examine the soundness of their current conceptions as well as discuss and test those beliefs (Cakiroglu, 2006). Misconceptions involve conceptual ideas and need to be addressed conceptually (Gooding & Metz, 2011).

An effective teaching strategy that can be used to challenge students' reasoning is the use of the conceptual change teaching approach (Alparslan et al., 2003; Yenilmez & Tekkaya, 2006). Conceptual change is a theoretical model in which learning is an active process and learners become aware of conceptual relationships and use reason to understand these relationships (Alparslan et al., 2003; Yenilmez & Tekkaya, 2006). This conceptual change theory is based on Piaget's ideas of assimilation, accommodation, and disequilibrium (Alparslan et al., 2003). This theory focuses on the circumstances needed in order for students' current conceptions to be modified by new conceptions (Alparslan et al., 2003).

According to Posner et al. (1982), this approach proposes that certain conditions must be met in order for a student to have his current concept be replaced by another concept. When a student faces an anomaly with her current conception, she can reject this anomaly as being a fluke or irrelevant, compartmentalize this knowledge to prevent conflict with her current beliefs, try to assimilate the new information into her current conception, or revise her existing conception (Posner et al., 1982). "The conceptual change approach proposes two types of conceptual change: *assimilation* that describes the process where students use existing concepts to deal with new phenomena and *accommodation*, which describes when students must replace their existing concepts" (Alparslan et al., 2003, p.134). In order for a student to change her way of thinking, she must first become dissatisfied with her existing conception; the new concept needs to provide a better explanation and be understandable (Posner et al., 1982). Then, the new concept must propose solutions to problems and be believable (Posner et al., 1982). Lastly, the new concept must be able to lead to new insights and discoveries (Posner et al., 1982). In this approach, learning involves an interaction between new and previous conceptions (Akpinar, 2007). If these conceptions can be reconciled, learning continues with ease. If they cannot be reconciled, the previous conceptions must be restructured or replaced with the new conceptions (Akpinar, 2007; Kowalski & Taylor, 2004).

Some successful methods for promoting conceptual change in science include inquiry-based activities, concept cartoons and conceptual change texts which can be paired with concept mapping or discussion webs. By using these instructional strategies, science teachers are able to identify and address students' misconceptions in photosynthesis and respiration.

Inquiry. The National Research Council (NRC) (2008) states, "students develop an understanding of the natural world when they are actively engaged in scientific inquiry—alone and with others" (p. 29). Thompson (2007) demonstrates an example of scientific inquiry through the "plant-in-a-jar" experiment. The experiment involves planting a small plant in an air-tight jar with moist soil (and a thermometer to monitor the temperature). Each group of students receives their own plant to observe for several months. The students make predictions about the outcome of the plant which usually state that the plant will die in a short period of time. A common misconception is that the plant will use up the water that enters its roots and reduce the total amount of water in the jar which will cause the plant to die. Every couple of days the students make qualitative and quantitative observations and record them in their journals. These observations include the number of leaves on the plant, plant height, the number of flowers, the temperature inside the jar, and descriptions of the plant, soil, and jar. Students also may draw or take a picture . After some time passes they may need to revise their estimates on the plant's lifespan based on their observations and class discussions. Other inquiry-based activities and discussions can help students better understand transpiration. In this activity, students sometimes think that the plant will use up the air inside the jar and die. The teacher can then lead the students in discussions about photosynthesis and respiration. When they are engaged in inquiry and reflect on this practice, students acquire a better understanding of science (Thompson, 2007). Another tool for helping students overcome misconceptions is the use of concept cartoons (Ekici et al., 2007).

Concept cartoons. Concept cartoons are cartoons that present the viewer with multiple scientific conceptions about an idea (Keogh & Naylor, 1999). The cartoons (see example, Appendix A) contain three to five students whose dialogue contains misconceptions and only one scientifically acceptable answer (Ekici et al., 2007). The concept cartoon helps lead the class into a discussion about which view is considered scientifically acceptable (Keogh & Naylor, 1999). Concept cartoons are successful instructional methods because they are visually appealing and stimulate student involvement in the lesson (Ekici et al., 2007). And more importantly, they identify and eliminate students' misconceptions (Ekici et al., 2007).

In the study performed by Ekici et al. (2007), 24 eighth-grade students were interviewed to determine what misconceptions they had about photosynthesis. Concept cartoons were then developed to help students think about the possible explanations for the specific concept, like food sources for plants as shown in figure 1 (see Appendix A). The class discussions allowed students to hear multiple explanations and challenge their own reasoning. Ekici et al. (2007) found that after the class discussions, all students were able to correctly identify food sources for plants. They also found that most students overcame their misconceptions in the topic of photosynthesis (Ekici et al., 2007).

Conceptual change texts. One way the conceptual change model can be put into practice is the use of conceptual change texts (Alparslan et al., 2003). In these texts, students are given the identified misconceptions first and then scientific explanations in order to create dissatisfaction (Alparslan et al., 2003). Alparslan et al. (2003) performed a study using conceptual change texts to promote conceptual change in students regarding respiration. The subjects of this study were 68 mixed-gender students from an urban area high school. The students, ranging in age from 16 to 17 years, were all in eleventh grade. One class was the control group and the other class was randomly assigned to be the experimental group. While the control group was taught with traditional instruction, the experimental group was taught using conceptual change instruction along with conceptual change texts. Results from this study show that students in the experimental group gained a better understanding of respiration concepts compared to students in the control group. All the students were given the Respiration Concepts Test before and after the instructional lessons were taught. The average percentage of correct responses in the pre-test was 48.5% for the experimental group and 41.5% for the control group. The same test was administered as the post-test and 77.4% of the experimental group gave correct responses while only 48.5% of the control group gave correct responses. Alparslan et al. (2003) determined that the scores in the pre-test were not statistically significant, but the scores in the post-test were statistically significant. By using the conceptual change texts, students were confronted with their own misconceptions, causing them to become dissatisfied with their current conceptions and more open to accept scientific explanations. These students participated in activities that helped them revise their current conceptions and allowed them to think and reflect on them (Alparslan et al., 2003). In order to teach using the conceptual change model, teachers need to give students enough time to identify and articulate their current conceptions, scrutinize the soundness of these conceptions and apply new ideas in a familiar context (Alparslan et al., 2003; Tekkaya, 2003). This teaching strategy is based on the theoretical model developed by Posner et al. (1982).

Concept maps. A slightly different approach to teaching using the conceptual change model is to use conceptual change text along with concept mapping strategy. Tekkaya (2003) performed a study to investigate the effectiveness of using this approach on students' understanding of diffusion and osmosis. The participants in this study included 44 male and female students from two ninth grade classes in an urban area high school. One class was randomly assigned to be the experimental group and the other class was the control group. Both groups received the same amount of instructional time, however, the experimental group was provided with concept maps and conceptual change texts. All participants took the Diffusion and Osmosis Diagnostic Test as a pre-test and a post-test. There was no significant difference found between the mean scores of the two groups for the pre-test. The experimental group performed significantly better than the control group for the post-test. The conceptual change method was more successful than the traditional method because the conceptual change approach explicitly addressed students' misconceptions while the other approach did not. This study supports the idea that it is not easy to overcome misconceptions, at least through use of traditional instruction. The important part of the conceptual change method of instruction was "the social interaction provided by teacher guided discussions" (Tekkaya, 2003, p. 13). A discussion web also gives students to opportunity to interact socially.

Discussion webs. Besides the concept mapping strategy, discussion webs can be paired with conceptual change texts as an instructional method under the conceptual change model (Yenilmez & Tekkaya, 2006). Discussion webs allow students to think individually about their ideas and then discuss them with others (Yenilmez & Tekkaya, 2006). They use a graphic aid which has a question or statement in the middle and students are asked to agree or disagree and state their reason (Yenilmez & Tekkaya, 2006). Then they discuss their ideas in a small group and reach a general consensus to present to the entire class (Yenilmez & Tekkaya, 2006). In a study by Yenilmez and Tekkaya (2006), 233 students in 8^{th}-grade were split into control and experimental groups to test learning via conceptual change texts and discussion webs. In this urban school, the students were taught by the same teacher using differing methods. The control group received traditional instruction while the experimental group used conceptual change texts and discussion webs. The traditional instruction included lecture/discussion to teach concepts with no thought of students' misconceptions. In the experimental group, the topics were introduced with questions and popular student misconceptions were pointed out explicitly. Students are expected to become dissatisfied with their current conceptions, making way for the scientifically acceptable explanations. The results of this study showed better performance by the experimental group than the control group. The conceptual change approach paired with discussion webs explicitly addressed students' misconceptions, which is needed in order for conceptual change to occur (Yenilmez & Tekkaya, 2006).

Identifying and addressing students' misconceptions are imperative for true understanding in science. Do middle school science teachers accurately identify common misconceptions that students have about photosynthesis and respiration? If so, what do teachers do to address them? Realizing the origins of misconceptions and becoming familiar with common photosynthesis and respiration misconceptions will help teachers to address their students' misconceptions directly so students can overcome them. Teachers also need to analyze their own understanding of science to discover if they are harboring any misconceptions of their own. Once they identify and address their own misconceptions, they can help students overcome theirs by using instructional methods that have been successful in prior research including inquiry, concept cartoons, and conceptual change texts.

Methodology

This study was designed to discover what middle school science teachers know about the misconceptions their students have about photosynthesis and respiration and what the teachers do to address them. In this qualitative empirical study, six middle school science teachers participated in semi-structured interviews where they were asked to respond orally to 14 questions in a one-on-one setting. The interviews were recorded and transcribed for analysis.

Participants

The participants in this study were six middle school general science teachers. The levels they taught ranged from grades five through eight. There were three female and three male participants who had been teaching for over 10 years. The participants differed in their certifications; three of them were science certified and three of them were not. However, one of the non-science certified teachers had some science background because he had a Master's degree in Curriculum of Science.

Certifications. Three of the teachers, A, B and C were science-certified in middle/high school and Teachers D, E and F were not (see Appendix E). All of the middle school science-certified teachers were also certified in high school biology/living environment. Two of the science certified teachers (A and C) have had experience teaching at the high school level. Two of the non-science certified teachers (D and F) have had additional experience teaching at elementary grade levels. Teacher E taught in the 5th grade, which was a middle school grade in that particular school district. The length of time teaching middle school science was considerably different for the teachers.

Teaching experience. All of the teachers had been teaching for over 10 years at the time of the study; however, they varied widely in their years of teaching the particular courses that address photosynthesis and plant respiration: middle school living environment (see Appendix E). At one end of the spectrum was a first-year middle school science teacher, Teacher D. Although she had taught other grade levels for 12 years, this was her first year teaching science exclusively and at the middle school level. At the other end of the spectrum was a teacher who had been teaching middle school living environment for 17 years. All of the teachers taught middle school living environment, also known as life science or biology, except for one participant, Teacher A, who was teaching physical science during the study but alternated teaching living environment and physical science. It had only been two years since Teacher A taught living environment in middle school. Teacher F taught life science but did not go in depth on the subjects of photosynthesis and respiration.

Setting

The middle school science teachers were from one high need/resource capacity urban or suburban school district and three average need/resource capacity school districts in western New York State (University of the State of New York, 2010). The schools (except one which was added later to provide more participants) were contacted via email to ask principals for permission to interview teachers in their respective schools and to find willing teachers to participate. Some participants were personally known by me, the researcher, some were found online on the schools' websites and some through suggestions from my colleagues. These middle school teachers were asked to participate in the study via email, phone, or by the school's principal and informed consent was obtained from all participants notifying them that their participation was voluntary and they could end their participation at any time (see Appendix B). I planned on having all the interviews in the teacher's room at the end of the school day, but that changed slightly to be more convenient for everyone. Four of the interviews were given in the teachers' individual classrooms at the end of the school day or during the teacher's prep. One interview was held in a coffee shop during spring break and one took place in the teacher's vehicle in the school parking lot before school started. A free honey bear or car wash coupon was offered as a gesture of thanks for participating in the study.

Methods

The participants were asked 14 interview questions (see Appendix C) orally in a one-on-one setting. The interviews were audio taped and transcribed. After the tapes were transcribed, the tapes were erased and the participants were given an alphabetical identifier to maintain confidentiality. The interviews lasted between 7 and 25 minutes.

The interview questions that were used were based on a study performed by Gomez-Zwiep (2008) who established the questions from a pilot study performed with 25 preservice teachers who were asked questions to determine the level of understanding in regards to students' misconceptions in science. Questions 2, 5, 6, 9 and 10 were taken directly from the study conducted by Gomez-Zwiep (2008). Questions 1, 3, 4, 7, 8, and 12 were reworded slightly and questions 11, 13, and 14 were added to address the specific needs of this study, which focused on photosynthesis and respiration and teachers' actions in addressing misconceptions. The original questions are listed in Appendix D. Some follow up questions were added during the interview depending on the participant's answers in order to clarify or expand upon the participant's responses.

The methods from Gomez-Zwiep's (2008) study were chosen based on the similar purpose of this study. The studies differ in the grade levels in which the participants teach; the previous study included primarily elementary teachers and some middle school science teachers while this study involves middle school science teachers exclusively. The studies also differ in that the Gomez-Zwiep (2008) study focused on science misconceptions in general whereas this study concentrated on photosynthesis and respiration.

Data Analysis

When analyzing the data, I looked to see whether or not my research question was answered by comparing the teachers' answers with the literature that I reviewed to find out if teachers knew that their students had misconceptions in these science topics. Furthermore, I looked to see if teachers knew the origins of students' misconceptions and the specific misconceptions common to photosynthesis and respiration. I also examined the data for emerging themes. I examined the data to see if non-science certified teachers differed in their understanding of their students' misconceptions in photosynthesis and respiration as compared to Biology-certified teachers (at the adolescent level). Another theme I looked for was the methods teachers used to identify and address students' misconceptions. I also reviewed to see if the majority of teachers used the same method to identify their students' misconceptions and if they used a particular instructional method to dispel misconceptions? In addition, I analyzed the length of time teaching middle school science so see if that had an affect the teachers' knowledge of students' misconceptions.

Limitations

One limitation of this study was the number of participants. Although the number of participants was small, there is a high value in the quality of answers, which gives readers a better understanding about the thinking and methods of middle school science teachers in western New York State. More limitations included gaining consent from teachers and principals. Even though the interviews did not take very long, teachers were very busy and did not have a lot of extra time to participate in a research study.

Findings

For this study, six interviews of middle school science teachers were conducted to discover if the teachers could accurately identify common misconceptions that students have about photosynthesis and respiration. The interview was also designed to answer the question, "What do these science teachers do to address their students' misconceptions?"

Teachers' Misconceptions About Misconceptions

The role of misconceptions plays an important role in science education. What is the impact if teachers have misconceptions about misconceptions? It makes sense to think that the first step in addressing misconceptions is being able to identify the origins of misconceptions but maybe the first step should be to understand what a misconception really is.

Definition of misconception. According to the New York State Science Teacher (2012), "misconceptions can be referred to as a preconceived notion or a conceptual misunderstanding." All of the teachers could give a simple definition of what a misconception is but none of them had a deep understanding of misconceptions. For example, Teacher E stated that a "Misconception would be like a misunderstanding of a particular idea." Teacher F defined a misconception as "a misunderstanding of a concept. Obviously misconception." Most of them stated that their students had no idea about certain science ideas but this does not fit into this definition of a misconception because in order for a student to have a misconception, she needs to have an idea to start with. Teacher C had the best understanding of what a misconception is, but this teacher also thought that having a misconception included not knowing a simple fact or definition. So, even though all of the subjects were able to give a basic definition of what a misconception is in words, they were not able to discuss what it means in application. Therefore, teachers actually have misconceptions about misconceptions. They need to become aware of their own misconceptions before they can address their students' misconceptions.

Addressing misconceptions. After the teachers were asked questions about what misconceptions their students had regarding photosynthesis and respiration, they stated what methods they have used to correct these misconceptions. According to the conceptual change model developed by Posner et al. (1982), teachers need to expose the misconception and propose the scientific explanation which also needs to provide solutions to problems and lead to new insights. Only one teacher stated that he used inquiry-based labs. As discussed in the literature, inquiry is one effective method that can be used to dispel misconceptions. Other teachers said they used traditional methods to address students' misconceptions, which research has shown does not work (Yenilmez & Tekkaya, 2006). This idea that the use of traditional methods is an effective strategy is another misconception of teachers. None of the teachers mentioned using the conceptual change model which research has shown to be an effective way to dispel misconceptions. Teachers think that traditional methods are effective and they are not.

Most of the teachers interviewed thought that students' misconceptions decreased as they continued to higher grade levels and that once the students learned these science topics they no longer harbored misconceptions. They also viewed misconceptions in terms of getting more or having less rather than keeping the same misconceptions and believing them more like a root growing deeper into the ground. Unfortunately, previous research contradicts this idea and shows that misconceptions are very difficult to change and must be addressed explicitly and purposefully. Only Teacher C was able to recognize this challenging task. He mentioned taking a class where he learned about a study that had interviewed college students about astronomy questions before and after teaching them scientifically correct concepts. Despite explicit instruction contradicting their initial understanding, the students still maintained their misconceptions. The longer a student believes a certain idea and has that idea reinforced, the harder it is to change that idea because it is embedded into his mind. Teacher E said that students could overcome their misconceptions depending on how motivated they were to learn about science. Teacher F also alluded to this idea that students' motivation in science is an indicator of how well students overcome misconceptions. A student can love science and be very interested in learning about science, but unless someone teaches him scientifically accurate concepts, all of the desire in the world is not going to help this student. Two-thirds of the non-science certified teachers had the misconception that misconceptions can be overcome by a student's motivation. This is just one example of the differences between science certified and non-science certified teachers.

Difference Between Certified and Non-Certified Science Teachers

The teachers in this study differed by certification and years of teaching at the middle school grade level. There was no difference found between teachers whose years of service differed, but there was a difference found between the fifth-grade teacher who taught multiple subjects and the sixth-grade teachers who taught science exclusively. However, considering the small sample size, I cannot draw any definitive conclusions. There was an observable difference between science certified teachers and non-science certified teachers. The science certified teachers had more knowledge of the origins of students' misconceptions and common misconceptions specific to photosynthesis and respiration.

Origins of students' misconceptions. All of the subjects were able to give examples of where students get their misconceptions which aligns with prior research; the reoccurring examples included TV, the internet, and other people including their parents. However, the science certified teachers also included other examples which are significant. Teacher C mentioned that students can get misconceptions from elementary teachers and from confusing illustrations in textbooks, which is supported by prior research. Subject B said, “When they look at an unexplained phenomenon they’re not sure [of,] instead of looking and finding the right scientific explanation they make up their own plausible explanation that fits with what they know at the time.” This answer concurs with the conceptual change theory, which postulates that sometimes students try to assimilate new phenomena into their existing knowledge and if the new concept does not fit into their old concept, a misconception is sometimes formed. The science certified teachers had a better knowledge of where misconceptions come from and how they are formed, which is a vital step in overcoming them.

Misconceptions in photosynthesis and respiration. The next step is for teachers to know what misconceptions their students have in specific topics. There was even more differentiation between the answers from the science certified teachers and the non-science certified teachers when they were asked what misconceptions their students have in regards to photosynthesis and respiration, if any (question 11). The science certified teachers were able to give some examples of their students’ misconceptions in these topics. For example, the common misconception that plants only photosynthesize and respiration is exclusive to animals. Another misconception that was mentioned included students confusing respiration with breathing. Teacher F, who was non-science certified, actually answered question 11 in terms of breathing, which is a common misconception. Teacher E did not believe that students have any misconceptions in photosynthesis and respiration. Teacher D was the only non-science certified teacher who was able to name a misconception specific to respiration and, even then, she was only able to name one. Science certified teachers had more knowledge about their students' misconceptions than non-science certified teachers.

It is unrealistic for teachers to expect their students to overcome their misconceptions unless the teachers accurately understand what a misconception is, know what misconceptions their students have, and offer research-based instruction to help students overcome their misconceptions. None of the teachers expressed a thorough knowledge in all three of these areas, but the science certified teachers did show that they had a greater understanding than the non-science certified teachers. There are several inferences that can be made based on this knowledge.

Discussion

The purpose of this study was to ascertain whether or not middle school science teachers could accurately identify and address common misconceptions that students have about photosynthesis and respiration. The results showed that teachers not only do not know what misconceptions their students have in these topics, but they do not even have a true understanding of what misconceptions are. They also do not know how to teach in a way that would help students overcome their misconceptions in photosynthesis and respiration. These findings support the prior research performed in this field.

Relation to Literature

This study confirmed the literature in that students have several misconceptions in photosynthesis and respiration. It was unfortunate to discover that some middle school science teachers do not have this realization. However, it was not necessarily surprising considering that the literature stated that misconceptions can come from teachers. Research has shown that if misconceptions are not addressed, they not only stay with that person but they also become more solidified in that person's mind which makes them even more difficult to change. None of the teachers who were interviewed realized this.

The teachers in this study were also unaware of some of the places their students get their misconceptions. Most of them only named the origins that they had no control over like parents and media. How students organize and interpret new ideas with their current ideas is, in my opinion, the biggest origin of misconceptions. Most of the teachers had no idea about this.

Considering the large number of misconceptions students demonstrated having in photosynthesis and respiration, it was also disconcerting that even the science certified middle school teachers were only able to name one or two misconceptions. This shows the lack of knowledge middle school science teachers have in the area of science misconceptions. There needs to be better training for science teachers and ongoing training to equip these teachers with the necessary knowledge needed to teach their students. Teachers also need to be equipped with the essential knowledge on lesson planning geared toward addressing students' misconceptions because all but one of the teachers in this study used traditional methods to address misconceptions, which prior research has shown to be ineffective.

Implications for Practice

Previous research has shown that preservice teachers harbor science misconceptions so college curricula needs to change to include exposing preservice teachers' misconceptions and educating these teachers on how misconceptions are formed or where they come from, common misconceptions in their field of study, and effective strategies to use with students to overcome misconceptions. Preservice teachers also need to be taught the definition of a misconception because there is, evidently, a lot of confusion about what a misconception is. In addition to making changes at the college level, schools and/or State regulations need to change to ensure that middle school teachers are highly trained in the subject they teach. Teachers who are not certified in science do not have the knowledge necessary to effectively teach middle school science. There was an obvious difference in the answers from the science certified teachers and the non-science certified teachers. The science certified teachers were more knowledgeable in the origins of misconceptions, misconceptions in photosynthesis and respiration, and overcoming misconceptions. There was a marked difference between these two groups; consequently there is indirect evidence that students would benefit from being taught by a science certified teacher.

Teachers could benefit from resources that help them identify and address common misconceptions. Textbook publishers could include explicit instructions on how to address students' misconceptions in teacher resource materials. Textbooks could include sample lesson plans with concept cartoons or conceptual change texts paired with discussion webs which have proven to be successful in helping students recognize and overcome their misconceptions. Teachers should also use pretests to identify what specific misconceptions their students have and use that information to plan their lessons. They should also use posttests to make sure students have changed their concepts and truly understand what was taught. Some of the teachers in this study said they use the end-of-year test to determine if their students have successfully overcome their misconceptions. However, they did not indicate that these tests include questions that test for conceptual understanding. Teachers need to examine their assessments as well as their lesson plans.

Implications for Future Research

In order to carry out these practices, research needs to be examined and/or performed to analyze assessments. More research could also be performed to determine if teaching science exclusively in middle school has an effect on knowledge of misconceptions. This study could be extended to include more questions about what happens to students' misconceptions when they are not addressed and scrutinize teachers' responses when they are shown evidence of students harboring misconceptions in high school and college. This study examined some of middle school science teachers' awareness of their students' misconceptions and can be expanded upon for future studies.

The purpose of this study was to discover if middle school science teachers could accurately identify common misconceptions that students have about photosynthesis and respiration and what teachers do to address them. Middle school science teachers have misconceptions about what misconceptions are and they do not know or use effective strategies to help their students overcome these misconceptions. Science certified teachers are more knowledgeable about the origins of misconceptions as well as common misconceptions in photosynthesis and respiration. In order for students to be successful in science, their misconceptions need to be exposed and addressed. Teachers need to be knowledgeable in science concepts in order to teach their students valid science. A science certified teacher has the educational background to be able to teach students about science better than a non science certified teacher. Science teachers would benefit from additional training about misconceptions (in general), common science misconceptions, and lesson planning to address misconceptions.

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Appendices

Appendix A

Food Sources of Plants Concept Cartoon

Figure 1. Concept cartoon of food sources of plants (Ekici et al., 2007).

Appendix B

Letter of Consent Form

Dear Middle School Science Teacher,

As I complete my master's degree at SUNY Fredonia, I have been researching student misconceptions in photosynthesis and respiration. I have prepared a 14-question interview for middle school science/biology teachers. The interview will take about 45-60 minutes and will be conducted in your classroom at the end of the school day. I plan to audiotape the interview. The information gained from this study will be helpful for teachers' planning and students' learning. Participation in this survey is strictly voluntary. By signing this consent form, you agree to participate in this study by answering questions and allowing your answers to be audio taped. In doing so, you will receive your choice of a honey bear or a coupon for a free car wash.

All information collected will be kept confidential. The names of the participants will be changed to numbered identifiers. Once the audiotape is transcribed, it will then be erased. You are free to withdraw from the study at any time without penalty. Also, if you are willing to participate in the interview, you are free to skip any questions that you do not feel comfortable answering. There are no risks associated with this study and the interview questions should not cause any distress or discomfort.

I have read and understand the consent form in its entirety, and I willingly give consent to participate in this study.

Signature ________________________________

If you have any questions, please feel free to contact the researcher, Nicole S. Kestler, Dr. Janeil Rey –Faculty Advisor, or Maggie Bryan-Peterson of SUNY Fredonia, listed below. Thank you for your time and willingness to participate in the interview.

Nicole S. Kestler

[redacted]

Dr. Janeil Rey –Faculty Advisor [redacted]

Maggie Bryan-Peterson, CRA [redacted]

Appendix C

Interview Questions

1.) What grade level do you currently teach?

2.) How long have you been teaching at this grade level?

3.) Have you had any experience teaching at another grade level?

4.) Are you science certified (if so, which science and at what grade levels)?

5.) What can you tell me about what a misconception is?

6.) How do people/students get science misconceptions? Where do they come from?

7.) What are some common biology misconceptions your students have had?

8.) As students advance in school, what happens to their science misconceptions?

9.) How does a student's misconception affect the success of your science teaching?

10.) How much do you think about misconceptions while you are planning a science lesson/before you teach a science lesson?

11.) What misconceptions do students have in regard to photosynthesis and respiration, if any?

12.) What have you done to help a student correct a misconception in photosynthesis and respiration?

13.) Has that been effective in dispelling students' misconceptions?

14.) How do you know a student has successfully overcome a science misconception?

Appendix D

Questions from Gomez-Zwiep (2008) Study

1. What grade level do you currently teach or plan to teach?

2. Are there any other grade levels you have experience with?

3. How long have you been teaching at this grade level?

4. How many science-related courses have you taken?

5. What can you tell me about what a misconception is?

6 How do people/students get science misconceptions? Where do they come from?

7. In your experience, what are some common science misconceptions your students have had?

8 As students grow and mature, what happens to their science misconceptions?

9. How does a student's misconception affect the success of your science teaching?

10. How much do you think about misconceptions while you are planning a science lesson/before you teach a science lesson?

11. What have you done to help a student mediate or correct a science misconception?

Appendix E

Teacher Experience

Teacher	Science-certified?	Years of Teaching	Years of teaching middle school life science
A	Y	23	12
B	Y	13	13
C	Y	>17	17
D	N	12	<1
E	N	>10	>10
F	N	14	11