

**Examining How Teaching Strategies Alter the Misconceptions  
of Middle School Science Students**

by

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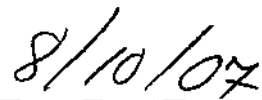
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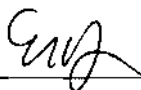
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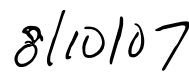
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## Chapter 1: Introduction

### *Problem Statement*

At the moment one enters the world, a wide array of learning takes place. People are constantly making observations with all five of their senses and trying to make understanding of the world around them. Sometimes the conclusions reached coincide with scientific findings, but many times opinions are formed that have misunderstandings at their roots. Once a person goes to school, they carry these misconceptions with them into the science classroom. The false understandings get in the way of acquiring new knowledge as they try to fit facts into their framework of knowledge. If not caught early, their misunderstandings compound and affect their measured success and achievement in class. Sometimes the misconceptions are recognized and sometimes they are not. A critical responsibility of a science educator is to identify these misconceptions, guide their students to “see” them, provide ways to come face to face with them, and finally make sure they have a correct understanding of science and how the world works. Additionally the students will feel success in science class and in the future. The reality is, if not addressed in school these misconceptions stay with students into all aspects of their lives.

### *Significance of Problem*

Imagine being a MIT graduate, having earned an admirable degree from an esteemed school. Whether or not that degree was in science one would think that a highly educated person like this could describe how a simple everyday light bulb is lit. Unfortunately this is simply not the case, as documented in the Private Universe Project (PUP, 1989), which is a prepared number of video tapes showing how many

graduates of Harvard, MIT and other leading institutions have the same misconceptions observed with children. In the documentary, graduate after graduate is not able to explain a basic electrical current, something that comes up in various science curriculums starting in elementary school (NRC, 1996). Even people who have gone through years of schooling can still hold onto the most basic misconceptions. These alternative ideas can affect a person's everyday life, whether or not they go into a science field or not. Especially today, citizens are asked to vote for candidates who support causes that include environmental policy, alternative energy resources, and many other issues relating to science content. If a person has various misconceptions about how the world works, they will consequently not be able to make informed and intelligent decisions on these topics. Misconceptions need to be remedied for life-long learning.

Misconceptions also get in the way of a students' success in the science classroom. Today, there are many standards students must meet in order to advance to the next levels of science. If a student has a misconception about a given topic and it goes undetected, achievement on high stakes tests could be affected. The resulting disappointment and failure could discourage students from entering scientific fields as a career choice (Tai, et.al. 2006). The frustration of a constant misunderstanding can also prevent a passion for science. One mission of a science educator should be to identify any misconceptions of their students, and encourage inquisitiveness to question and change the false perceptions. Practicing the nature of science in the

classroom helps to change misconceptions and foster an excitement for the scientific field. Misconceptions have long-term consequences.

### *Purpose*

The purpose of this study is to answer the following questions:

#### **1.) How do teaching strategies alter students' misconceptions?**

Science educators have a large responsibility in trying to change students' misconceptions. Identifying and restructuring permanently does not just happen with a quick fix, but through time tested teaching strategies. This study will use student-centered teaching strategies like guided inquiry and problem solving that are rooted in small group discussion to foster conceptual change. Once the student engages in student-centered instruction specific to their misconception, the hope is he or she will restructure their thinking to accommodate the appropriate scientific concept.

#### **2.) Within the teaching strategies used, what do students' attribute their increased understanding of science concepts?**

Today's students are energetic and enjoy engaging in interactive learning. This question will hopefully answer what student's opinions and attitudes are towards the various teaching strategies used. Through this self-reflective process students hopefully will gain insight into how each learns best.

### *Rationale*

The primary goal of this project is to gain knowledge about altering students' misconceptions in hopes to design instructional lessons that:



(1.) Identify student misconceptions, and match their learning to directly address the misconception. Finding what the students know first is key, and then grouping them according to their misconceptions will use a differentiated approach to address the most students. (2.) Alter student misconceptions through student-centered instructional strategies. By allowing students to investigate their own misconceptions in a guided inquiry and problem solving setting, students will take ownership of their learning and more conceptual change will occur. (3.) Use small group discussion and reflection to reinforce learning. The use of guided discussion allows the misconception to be changed more permanently. (4.) Motivate students to engage in learning. By using student-centered instruction and small group discussion, students will learn more through these personal experiences. Students will be encouraged to take ownership of their learning since the instructor is not passively giving it to them in front of a classroom. Hopefully, they will ultimately enjoy this type of learning and see the excitement a real scientist can experience. (5.) Will change how the educator instructs. Instead of the traditional lecturer, the teacher must view his or her self as a guide, and not a dispenser of information. If the students are just told what is right or wrong in their thinking, this is not permanent or meaningful.

### *Summary*

Misconceptions in science are common in students that affect how they learn, and how they view life. Changing these misconceptions should be a primary role of the science educator. Through student-centered instruction like guided inquiry and problem solving strategies, students are forced to take ownership of their learning and

restructure their frameworks to fit new science concepts. Reinforced by guided discussion and differentiated to meet each individual student's needs will allow the most conceptual change to occur. Student's attitudes through active participation will hopefully be positive, as they become better life-long learners.

## Chapter 2: Literature Review

The common definition of the word misconception is an erroneous conception or a mistaken notion ('Misconception,' n.d.). The belief of an incorrect fact does not constitute a misconception. Incorrect facts can be erased easily by communicating the proper information. However, a misconception includes a deep framework of conceptual thinking that has perpetuated through many years. Bahar (2003) summarizes misconceptions as corresponding to concepts that have peculiar interpretations and meanings in students' explanations that are not scientifically accurate, that is, nature does not bear out as observable what a person may "think." Some researchers prefer to call misconceptions "alternative frameworks" or "alternative conceptions" in an effort to show intellectual respect to the learner who holds those ideas (Bahar, 2003). In essence, researchers believe the person is not necessarily wrong by their own accord, they simply see an explanation in a different light. "Naïve conceptions" is another term used to label misconceptions. "Naïve conceptions" emphasizes the developmental nature of learning, and indicates the conceptions have come from children trying to explain their environment (Ridgeway & Dunston,

2000). Regardless of how misconceptions are labeled in research, they still refer to an understanding that contradicts current scientific thought.

Determining the titles of misconceptions should not be the primary goal of a science educator (Modell et.al., 2005). The language and various definitions of misconceptions are confusing, and can be overwhelming. Rather, the focus should be on discovering where the misconceptions take root, and then developing strategies to transplant them. Identifying and changing misconceptions are the far more important goals.

Misconceptions in science can originate from a variety of sources. Misconceptions can occur when the learner is trying to make sense of a situation or phenomena in their environment. Often, these misconceptions happen at a very early age. Misconceptions can formulate due to several reasons. Some reasons include cultural beliefs, encounters with other people including family members, and observations of others (Chin & Chia, 2004). Often, a parent will try to explain something to their child, and, unknowingly, a misconception will form. Teachers can also be guilty of cultivating misconceptions when their own scientific knowledge is weak, and their confidence in the material is low (Jarvis & McKeon, 2005). Clearly, misconceptions can be formed and still persist throughout school.

Science concepts, by nature, can be very abstract and counterintuitive. As a result, the concepts can be difficult to comprehend (Ridgeway & Dunston, 2000). For example, Campanario (2002) reports that according to our daily experience, an object will only move if an outside force acts upon it. Campanario's example reinforces the

fact that there are misconceptions with the topic of motion. Unfortunately, the misconceptions often grow unnoticed because of their continual presence in daily life. Students constantly encounter these types of common experiences, and then form explanations of how the world works in their own frameworks. Another common example refers to a student's perception of why we have seasons. When asked this question, many students will respond that the earth is closer to the sun during summer, and farther away during winter. They use an experience, like how they feel when standing next to a heater, and then apply it to how they feel during the summer. Through schooling this misconception often gets reinforced when looking at diagrams that seem to show the earth being far away and close to the sun at certain points in its orbit. The truth is, the earth's orbit is practically a perfect circle and the Northern Hemisphere is actually at its closest point to the sun during the winter (PUP, 1989). Students will commonly have beliefs like the orbit example and unfortunately these explanations often do not match up with scientific thought.

It is common for misconceptions to occur in all divisions of scientific study. Misconceptions in physics include topics in force, motion, friction, and gravity (Eryilmaz, 2002; PUP, 1989). Ecology misconceptions have not been studied as extensively, but can include ideas on population growth in ecosystems (Munson, 1994). Earth science misconceptions deal extensively with the structure of the earth and astronomy (Chang & Barufaldi, 1999; Dorsey, 2006). Misconceptions about common scientific measurements like density are also frequent, especially in middle school students (Doran & Burke, 2006).

When a misconception is never corrected, there are a variety of negative consequences. If a misconception is not changed, it can be passed down through generations, leading to a perpetuating uneducated population (Chin & Chia, 2004). Besides going through life with a wrong understanding, students' success in college can be directly affected. The more experiences students have in high school that emphasize changing their misconceptions, the better they do in college science courses (Tai, et.al. 2006). The value of changing misconceptions is seen in all stages of life.

### *Constructivist Theory of Learning*

So how does one change these misconceptions? The idea is rooted in the constructivist theory of learning. The model of constructivism is attributed to many different philosophers and psychologists throughout history including Piaget and Vygotsky. Constructivist thought says that new knowledge is constructed by the learner as experiences are interpreted with the respect to existing frameworks (Weaver, 1998). Vygotsky is attributed with emphasizing collaboration between learners in the constructivist model (Vianna & Stetsenko, 2006). Piaget focused on the learning process, where teaching's role was to always guide learning, and not worry so much about the teaching (Vianna & Stetsenko, 2006). Sometimes the experiences can be added and sometimes they cannot, according to the existing foundations. The student is building his or her knowledge base by associating and then linking new ideas with already established ones. New knowledge must be reorganized into a model that then associates it with itself and with the older models

(Modell et.al, 2005). Constructivist teaching offers students many chances to develop higher level thinking skills like thinking critically, make judgments based on data, and apply concepts to solve problems (Burrowes, 2003.) Constructivism focuses on the general process of learning and forms the foundation of thought for how to remedy misconceptions.

### *Conceptual Change Theory*

The theory that takes constructivism and then focuses specifically on the exact conditions needed for misconceptions to be modified by new information is called the conceptual change theory (Weaver, 1998). Conceptual change theory takes constructivism as its foundation, and addresses how thoughts must be altered in order to coincide with scientific theory. Posner et.al. (1982) is attributed with advancing conceptual change theory in his study, "Accommodation of a scientific conception: Toward a theory of conceptual change." Posner proposed conditions that must exist in order for conceptual change to occur. In summary a student must be dissatisfied with their existing conceptions. Then the new conception must be intelligible, plausible, and fruitful (Cobern, 1996; Ridgeway & Dunston, 2000; Weaver, 1997). In order for a student to fully adopt the correct thought, the conception must explain the old experiences in a new way and explain any future ideas to come.

Based on conceptual change theory, one of the first steps in remedying misconceptions is the identification of one by the learner and teacher. It is important to identify a misconception, because then there is a better chance at changing it (Uzuntiryaki & Geban, 2005). There are various strategies that have been suggested

in both cases. For this process to even begin, teachers, as the individual with the correct scientific knowledge, must recognize the specific misconceptions their students have. In true constructivist thought, Mintzes and Wandersee (1998) state, “the single most important factor influencing learning is what the learner already knows” (p. 81). Unfortunately, even though many teachers agree with the previous statement, according to the study done by Morrison & Lederman (2003) very few teachers truly tap into a student’s prior knowledge and then design lessons that address them. Many can recite the importance of pre-teaching, but besides superficial questioning and broad classroom discussions, a student’s prior knowledge is not assessed. Various pre-teaching techniques are suggested to remedy the problem of teachers assessing students before the lesson. The use of concept maps, pre-tests, interviews, and writing prompts are known formal strategies. Even the teacher just having the knowledge of common misconceptions in each content area is important. Morrison & Lederman (1998) suggest that teachers should be provided with pre-made lists of common misconceptions in their content area before they even start teaching. Usually, veteran teachers have made mental lists of misconceptions over the years of their career, but would not it be beneficial for all to possess this knowledge right from the start? Michael (2002) is trying to gather a comprehensive list of students’ misconceptions in physiology. His plea was published in *Advances in Physiology Education* as an effort to increase communication between educators. The pre-determined common misconception lists would not be a substitute to still gathering the particular student’s personal misconceptions, but it would be a good starting place

to know where to look. The teacher recognizing a misconception is the first step. Next it must be brought to the students' attention.

For the student to realize he or she holds a misconception, usually just telling them he or she has one is not enough. A considerable amount of intentional teaching is necessary. Purposeful teaching is very important because even though educators feel a very strong responsibility towards their students, students are the only ones that can ultimately modify his or her misconception (Modell et.al., 2005). In order to change a misconception, students must recognize a difficulty exists and that his or her misconceptions are leading to incorrect conclusions. In other words, the student must experience a "conceptual conflict" in order to truly make a change (Ridgeway & Dunston, 2000). Conceptual conflict entails that the student must be dissatisfied with his or her personal understanding, and must see value in correcting his or her beliefs. Strategies to accomplish conceptual change may be very simple; it just depends on the student and his or her particular misconception. Often just questioning and encouraging the student to look at the given topic from a different point of view helps him or her to recognize his or her view does not coincide from all angles. Sometimes the realization point may be accomplished using a tool called conceptual change text (Uzuntiryaki & Geban, 2005). In conceptual change text, students are asked to predict what would happen in a situation using his or her misconception. The text then presents evidence that illustrates how his or her misconception would lead to an incorrect prediction. The text provides the students with conceptual conflict as he or she realizes that his or her own existing knowledge is insufficient. Other times



conceptual change takes a hands-on experience in a laboratory setting or a demonstration. A “discrepant event” is the term used by some researchers to describe a situation or demonstration that might bring the student to “conceptual conflict” (Ridgeway & Dunston, 2000). The term discrepant event is used because the scientific phenomena students are observing or experiencing is not explainable in their framework.

### *Teaching Strategies to Alter Misconceptions*

The next step in the conceptual change process is how to fix the misconception. This includes a wide-range of researched strategies. Something all the strategies have in common is that they directly address the misconceptions through meaningful learning, as opposed to rote memorization. Unfortunately the present school system focuses too much on rote memorization, preparing students for tests with facts that are quickly forgotten. Students and educators alike easily get used to this type of learning, and misconceptions will not get fixed using this method (Novak, 2002). It is necessary to implement student-centered, constructivist experiences for meaningful learning to occur. Student-centered activities are also known as active learning, where the students are involved in the process and they must think for themselves (Burrowes, 2003). A constructivist learning activity is an experience that builds on old concepts while adding new ones. The catch is when altering misconceptions; the old concepts also have to be changed. Processes that actual scientists use like inquiry and problem solving are strategies that are considered student-centered and based in constructivist thought (Udovic et.al., 2002).

Other strategies can also include project-based learning with problem solving strategies, the use of guiding questions, and student collaboration (Rosenfeld & Rosenfeld, 2006). In this study students will directly address their own misconceptions in a collaborative setting using guided inquiry and problem solving skills.

### *Guided Inquiry*

Much praise is often given to an activity that is labeled hands-on. However, lab activities that require students to move and work hands-on are not guaranteed to cause conceptual change (McGregor, 2004). A student must be required to come face-to-face with his or her misconception personally, and then be guided through the change process. One of the best ways to do this is through a guided inquiry lab (Weaver, 1998). A guided inquiry lab should have certain criteria that will lead the student to the goal of restructuring his or her misconception; it is not just an open-ended search for some random answer. Keefer (1999) includes the following in his criteria for inquiry labs: students must have a problem to solve. The particular problem will directly address their misconception and does not allow for numerous conclusions, but the one they are looking for. Students must know they can solve the initial problem. When conceptual change is occurring, the student must realize there is a correct answer out there, and they are not just blindly searching. Students must have background information accessible to them. The background information may entail the teacher providing it in a constructivist format, or students may be able to *acquire it themselves through various resources. Students must come to realize that*

their way is incorrect. This applies to the “conceptual conflict” that must arise in students in order for change to occur. Next criteria is that students will see the correct concept and that they will be given time to work it out. Lastly, the teacher should be providing checkpoints with the students to make sure they are on track and they should experience success. The development of these criteria was the result of an eight-year study on inquiry and these aspects allowed students to learn science for short and long terms. The use of science process skills involved in inquiry includes predicting, designing experiments, and analyzing data. Putting these three aspects together where students must verify their prediction has a better chance at changing students’ misconceptions permanently. Students come away stating they understand the new concepts in greater depth as well (Deters, 2005). Since students have to think so thoroughly about what they are doing, they understand and reconstruct their knowledge to a more intense level. In addition, students are motivated because they are doing something they enjoy and consequently are engaged in hands-on types of laboratory learning (Weaver, 1998; Deters, 2005).

The teacher’s role in guided inquiry activities may be different than the traditional teacher role. First, teachers are not supposed to tell students the answers outright, as the students are supposed to search for them themselves. There are several approaches that teachers can use to avoid giving answers. Three particular suggestions are outlined in Furtak’s (2006) study. Some teachers may want to treat the investigation as a game, accept his or her student’s ideas with out evaluation, or by rationalizing why he or she is not giving answers as a teaching strategy. There has

not been a perfect way to deal with avoiding giving answers, as much depends on the individual teacher's personality and relationship with his or her students. A teacher must also guide students towards correct answers without giving them the answers outright. Li's et.al. (2006) study gives a good demonstration of a teacher using leading questions to guide students to the correct answer. The study shows a teacher encouraging students to try various tests that will lead them to the realization that their misconception needs to be revised. The teacher's role can be very implemental in the revision of misconceptions and there is a strong need for the training of teachers in how to define the role.

The alternative to guided inquiry is a cookbook lab where students just follow a set of steps for a verified outcome. Cookbook labs do not use higher-order thinking skills, make it easier for a student to lose interest, and do not correct students' misconceptions. Inquiry labs have a 75% chance at correcting misconceptions, while cookbook labs only have a 30% chance (Michael, 2002).

Interest and motivation are important fuels for the conception change fire. The conceptual change process tends to move along when a student is motivated to increase his or her understanding. Attitude and motivation is important because students with positive attitudes tend to make a greater effort (O'Connell-McManus et.al., 2003). Greater effort leads to a greater chance of a student changing his or her own misconception. Students at all grade levels, elementary, middle and secondary, have expressed that the use of hands-on activities such as labs help maintain their interest in the subject matter (Weaver, 1998). When students see relevance in the

activity they are doing, willingness to engage in the activity is no longer a problem. Deters' (2005) study looked even more specifically at hands-on inquiry labs. Deters' study found that most students think it is more exciting and worthwhile to work on their own creation, instead of always following regimented steps or processes. Maintaining interest will allow students to take ownership in their learning, and be more open for conceptual change to occur.

### *Problem Solving*

Problem solving skills help students through inquiry situations. Problem solving skills also help students come to terms with the conflict between their misconception and the correct scientific concept (Pizzini, et.al. 1989). As students must search for the answers to solve a given problem, they are personally restructuring their own processing framework. The Search, Solve, Create, and Share (SSCS) model for problem solving was created by Ed Pizzini, et.al. (1989) as a simplified process where students can re-enter into the various problem-solving steps at anytime. The SSCS process is known for its few and simple steps that are not a pre-packaged curriculum, but can be applied to various contents and classes. The Search phase consists of students determining a problem or question to study. The Solve step is where students generate and implement their plans for finding a solution to the problem. The students may find they solve the problem, or they may have to enter back into the search phase and modify their initial question. The model is flexible for this. The Create phase allows for a creative manner for the students to communicate their results. Their creation must show any conclusions they have

reached as well as comparisons between the data, their solution, and their initial beliefs. The last phase, Share, is where students share what they found with their classmates and reflect on what others share. The teacher's role in this problem solving situation is the same as during guided inquiry. Since guided inquiry and problem solving really go together, this would be expected. The teacher acts as the facilitator in the classroom assisting students in brainstorming strategies to solve their problem. The teacher challenges and helps students to see all possibilities. The teacher should be non-judgmental as they prompt ideas, but also be holding the students responsible for their learning. Chang & Barufald's (1999) study found that the SSCS model was a good strategy to reduce student's misconceptions as opposed to a traditional teacher-lecture method. Pizzini's model also increased student achievement on application level questioning. The teacher must prepare the students with the proper tools and resources when doing a problem-solving activity. If students do not know how to use the proper tools, they will become frustrated and discouraged (Vianna & Stetsenko, 2006).

The opposite of a hands-on, student-centered, active learning model is a lecture based, teacher-centered approach. Just as there is research supporting the student-centered model, there is research against lecture learning. Lecture teaching is also known as traditional teaching. Traditional teaching requires the teacher to act as a knowledge source, a dispenser of facts and content. Assessment is always based on pencil and paper tests (Rosenfeld & Rosenfeld, 2006). The results of traditional teaching have been a lack of student motivation, poor content retention, few scientific

skills, and the inability to apply concepts (Burrowes, 2003). The same study found that active learning is more effective than traditional instruction in promoting academic achievement, increasing conceptual understanding, and enhancing students interest in biology. Another study comparing lecture learning to student-centered learning found the more students are actively involved, the more their science achievement and attitude test scores increased (O'Connell-McManus et.al., 2003). An additional study focused on trying to depart from full lecture teaching. By implementing inquiry based problem-solving sessions, student achievement increased on culminating examinations (Lewis & Lewis, 2005). The research clearly supports active learning as an effective method for increasing student achievement and decreasing misconceptions.

### *Guided Discussion*

Research has also documented the importance of peer or teacher guided discussion in the conceptual change process. Students talking to each other and reflecting on what has been learned provide the opportunity to evaluate why particular misconceptions are present (Chang & Barufaldi, 1999). The discussions must be guided and monitored, so students do not reinforce each others' misconceptions (Jarvis & McKeon, 2005). De-briefing sessions after a student-centered learning session is vital to uncover and correct student misconceptions (Deters, 2005).

### *Differentiated Instruction*

The one-size-fits-all model is not sufficient when correcting misconceptions. Many students have different misconceptions about a similar topic. Still other students are labeled with learning disabilities and may need various supports for learning. If the educator treats all of these students the same way, the maximum amount of learning will not take place. To provide support for all students, strategies used must take into account the diversity of the student's readiness, interests, and learning profile (Tomlinson, 2001). Differentiating the instruction is key in helping correct misconceptions. When grouping students for guided inquiry, students with common misconceptions and interests should be grouped together. Homogeneous grouping allows the focus to be on a similar topic. Students also should be encouraged to work at their own pace, and use each other as peer-tutors, similar to the study by Mastropieri & Scruggs et.al. (2006). Mastropieri & Scruggs et.al. (2006) found that differentiated learning activities with peer partners was effective at increasing student achievement on content post tests and high stakes end of year post tests. For students with learning disabilities, the guided inquiry teaching strategy may need to be differentiated in response to the study by Mastropieri, Scruggs & Butcher (1997). Guided inquiry was highly successful for the general population, but more structure must be provided for the students with learning disabilities in order to have similar success. According to the study completed by Mastropieri, Scuggs & Butcher (1997), if learning disabled students were let loose to discover whatever they could about the topic, little to no learning took place. Instead, students should be grouped at similar readiness levels, and then given more guidance than a general education



group. It was suggested that perhaps the students should be told what rule or concept they are looking for, and then they should question it and test it, instead of just trying to discover the rule. Assisting the students with scaffolding achieved more learning for students with learning disabilities. For the inclusive science classroom, differentiation is important in order to reach all learners.

Conceptual change is not an easy process. It takes time, proactive strategies, discussion, and a constant revisiting of the concepts. The resistance to conceptual change by students is a reality that is also observed in the scientific community. According to Campanario's (2002) evaluation, numerous scientists who won the Nobel Prize crafted papers reporting their award-winning discoveries were originally rejected by scientific journals. Slow turnover time for the scientific community parallels students' hesitation to give up their misconception. Campanario's (2002) suggestion is to include examples of real-life resistance to change when teaching the students. Students need to learn that it is acceptable to hold a wrong idea, admit their conception is incorrect, and work to understand the correct idea. Students are sometimes overly concerned with getting the right answer. Consequently, students would rather hold on to old misconceptions, rather than admit that they were wrong and go through the process of re-explaining it to themselves. If students were informed that it is good science to be wrong, to evaluate new information, and then change one's ideas, perhaps the slow process of conceptual change would be decreased.

Students holding misconceptions in science is very common. Educators must guide students through the process of correcting misconceptions by identifying them, eliciting conceptual conflict, and then implementing strategies that will guide them through the process of correcting them. These strategies are rooted in constructivist and conceptual change theories of teaching. By differentiating by particular student's misconceptions, there is a higher chance of correcting the misconceptions. Creating homogeneous groups according to each misconception shows students the relevance of the learning, and they in turn are motivated. Using student-centered learning, such as guided inquiry and problem solving skills, forces students to confront misconceptions and use critical thinking. The use of reflection and peer-discussion also helps seal the process and prevent the formation of further misconceptions. Making sure students do not maintain current misconceptions, or form new misconceptions, will help them be more successful in future classes and in life.

### Chapter 3: Applications and Evaluation

#### *Introduction: Target Group and Goals*

Although educational literature supports the process of teachers being able to alter students' misconceptions using well-researched teaching strategies, there is still much to be learned specifically in the area of middle school science. An action research project testing how teaching strategies can alter students' misconceptions was conducted in an eighth grade physical science classroom during May and June of 2007 at a small suburban/rural school in Western New York.

The initial investigation was carried out to explore the efficacy of student-centered, constructivist activities with guided discussion on altering students' misconceptions in middle school science. The study was differentiated by each student's particular misconceptions with an emphasis on guided inquiry and problem solving based learning. The research questions that drove the study included: (1.) How do teaching strategies alter students' misconceptions? (2.) Within the teaching strategies used, what do students attribute their increased understanding of science concepts?

### *Participants*

The participants in the study were all enrolled in an introductory physical science course. Students were in one of five classes taught by the same teacher. Of the eighty-four students invited, fifty-five chose to participate in the study. The participants were assumed to represent a random sample of varying gender, special education students, and different ability levels. All students participated in five 42 minutes class periods each week.

### *Procedures of Study*

The study was introduced around the parameters of a culminating project at the end of a two-year loop with the students. The teacher taught the students in seventh grade life science as well, since looping is the practice at the school. It took place over a period of two and a half weeks at the end of the participants eighth grade year. Students first completed a pre-survey during class time with nine questions about previously identified misconceptions in the middle school science content.

Based on their answers, students were grouped according to similar misconceptions. The four most prevalent misconceptions were as follows: how the digestive and excretory systems are different and work together, how an object shows a particular color, how water droplets are formed on a cold drink, and how the earth has seasons. The topics also became the four different study groups. Of the fifty-five student participants, nine were in the Digestive and Excretory Group, fourteen in the Color and Light Group, twenty-five in the Condensation Group, and seven in the Earth's Seasons Group. The sampling in the above distribution was representative of the entire class population. Since the students were matched with their own misconception, one particular class period could have one of each of the four groups or duplicate groups, depending on the misconceptions present. Each class period had four to six groups total. During the next two and a half weeks, students were guided through the problem solving strategy Search, Solve, Create, Share (Pizzini et.al., 1989; Chang & Barufaldi, 1999) to investigate their particular misconception. The participants used student-centered inquiry skills to research on the computer, and hopefully create a lab-like test to prove a particular fact about their topic. There was no control group, but rather the freedom of a "free curriculum" as students searched for answers to their own misconceptions. Changes in students' misconceptions, as well as what they attributed their learning to, were then analyzed using a misconception post-survey and analysis of a product they created. A random sample of 11 students were invited to participate in an audio taped interview allowing them to elaborate on selected questions from the misconception post-survey. The intensive and student-

centered nature of the study was designed to allow for students to restructure their own thinking and alter a particular misconception.

### *Instruments for Study*

*Pre-Survey.* Prior to instruction, students were given a pre-survey developed by the teacher which included nine open-ended questions in the areas of life, physical, and earth science content (Figure 1). Modeled after the Alternative Frameworks Survey (AFS) instrument in the Chang & Barufaldi study (1999) the questions were opened ended to encourage students to express their opinions thoroughly. Like the AFS instrument as well, the directions also asked students to express everything they knew about the question and to use lots of details or even pictures when appropriate. All of the topics in the nine questions were part of the seventh and eighth grade science curriculum, and had been taught by the teacher in the past two years. The nine question's topics were also determined as common student misconceptions in middle school by the teacher, another middle school teacher at the school, and through the research of the educational literature (Bahar, 2003; Campanario, 2002; Chang & Barufaldi, 1999; Doran & Burke, 2006; Dorsey, 2006; Eryilmaz, 2002; Munson, 1994; PUP, 1989).

### Figure 1. Pre-Survey Questions

1. Explain how you know something is alive.
2. Explain how an organism maintains homeostasis.
3. Explain how the digestive and excretory systems are different. Explain how they work together.
4. Explain what causes an object to float or sink. How would you predict this?
5. Explain how an object's density would change if you cut the object in half. Explain how you know this.

6. Explain how an object displays a particular color. Explain how a red apple would look in a completely dark room.
7. Explain what causes a cold drink to have water droplets on it during a hot day. Where do the water droplets come from? What causes them?
8. Explain what causes volcanoes and earthquakes. Explain how you know this.
9. Explain what causes the earth to have seasons. Explain how you know this.

The pre-survey was then analyzed using the categorization system used by Chang & Barufaldi (1999), adapted from Simpson & Marek (1988). Each response was classified as the following: (1) an understanding- students are able to clarify their understanding of a science concept which is also consistent with the established scientific views, (2) partial understanding- students have acquired some understanding of a science concept although these ideas are not expressed in an integrated or unified way, (3) clearly evident misconception- students provide one simplistic, incongruent viewpoint different from those of scientists, (4) confused, faulty outcomes- students' explanations of a natural phenomenon are confused and contradictory to each other, and (5) no conception- students leave the question blank. Using the questions that students scored a three or four on, students were then placed in groups with fellow students with similar misconceptions. If a student did not score a three or four on any of their responses, they were placed in a group that they seemed to have a weaker response to, perhaps a five or a two.

*Post-Survey.* At the conclusion of instruction, students then completed a six-question post-survey (Figure 2). The first question was the same question from the pre-survey matching their misconception group. The student's response was again analyzed using the Simpson & Marek (1988) system and compared to their pre-

survey score for that particular question. The comparison of the pre- and post- survey question responses was used to address the research question 1: How do teaching strategies alter students' misconceptions?

The remaining five post-survey questions were designed to address the second research question: Within the teaching strategies used, what do students' attribute their increased understanding of science concepts? Where did they feel they learned the most, and compared to traditional teaching were they more motivated, did they enjoy the process?

Figure 2. Post-Survey Questions

1. Same question that matched your particular misconception group from the pre-survey.
2. Where did you get the above idea? How do you know what you know?
3. At what point in the past few weeks do you feel you solved your misconception? For example, was it during a small group discussion, research with your group, or a specific problem solving phase (Search, Solve, Create, Share)? Explain in detail why you think it was at this particular point.
4. In your opinion, what are the advantages and disadvantages of learning in small group, problem-solving classroom like we did the past few weeks?  
Advantages: Disadvantages:
5. Do you prefer doing a lab where the teacher gives you the steps to perform, or would you rather create your own investigation like you did these past few weeks? Explain your answer.
6. Any other thoughts you would like to add about this class or this project?

*Student Work.* At the end of the investigation process, the students had to create some type of product that demonstrated what they had learned over the previous two and a half weeks. The product was part of the Create Phase of SSCS. The students then had to present their product to the rest of the class as part of the Share Phase of SSCS. The groups were encouraged to be creative with their product.

Some examples were power-point presentations, or authoring a children's book. The written work and spoken presentations were graded for scientific accuracy using a five-point scaled rubric: 5- misconception has been altered, explanations include correct scientific facts, able to explain in detail their topic and tests using proper terms; 3- still holds a partial misconception, explanations include a few correct scientific facts, able to explain some aspects of their topic and tests using proper terms; 1- still holds a misconception, explanations do not include scientific facts, not able to explain their topic or tests. Scores of 4 and 2 fell in between the given parameters. The analysis of student work was used to answer research question 1: How do teaching strategies alter students' misconceptions?

*Interviews.* Student interviews were conducted for two purposes. First, seven students were individually interviewed to elaborate on the first question on their post-survey. Two students participated from each of the Color and Light, Condensation, and Earth's Seasons groups. One student participated from the Digestive and Excretory group. All participants were randomly selected from different class periods and included males and females. The interviews were audio taped and took place at mutually agreed upon times. The students were able to look at their post-survey responses, and further explain their answers. The seven student interviews helped answer research question 1: How do teaching strategies alter students' misconceptions?

In the second interview four students were interviewed as a group and were asked to elaborate on the remaining post-survey questions. The focus in the interview



included what the students perceived as positives and negatives to the process and whether they felt the investigation was beneficial to them. Again, the participants were from varying class periods, included two boys and two girls, and represented the several misconception groups. The interview was audio taped and took place at a mutually agreed upon time. The four students interviewed helped answer research question 2: Within the teaching strategies used, what do students attribute their increased understanding of science concepts?

#### Chapter 4: Results

##### *How do teaching strategies alter students' misconceptions?*

Pre- and Post-Survey scores were compared to see how students had altered their misconceptions. After analyzing and categorizing the students' responses using the Simpson & Marek (1988) system, Table 1 describes the percentage of students who now could demonstrate a score of a (1): an understanding- students are able to clarify their understanding of a science concept which is also consistent with the established scientific views. Table 1 also reports the percentage of students who could demonstrate a score of a one for each particular misconception group. The final column describes the percentage of students that may not have demonstrated a score of one, an understanding, but rather any sort of improvement in understanding from their pre-survey score. Maintaining the same score, or declining scores were not counted with this percentage.

Table 1. Pre- and Post-Survey Scores Compared

	Students that now score a (1): an understanding	Students that improved their pre- to post-survey score.
All Groups	49%	82%
Digestive and Excretory	11%	33%
Color and Light	50%	86%
Condensation	56%	92%
Earth's Seasons	71%	100%

The majority of students in all groups showed an increase in understanding (82%), with almost half of them demonstrating complete understanding of the concept (49%). Depending on the particular misconception group, the percentages still varied substantially with the Digestive and Excretory group showing the least understanding or improvement, 11% and 33% respectfully. The Earth's Seasons group showed the most understanding and most improvement, 71% and 100% respectfully. The scores and eventual percentages were only based on what the student wrote on their survey, student interviews revealed more information.

Individual student interviews were conducted to give the students the opportunity to further explain their written post-survey answer. Of the seven students interviewed, all except one demonstrated an increased understanding of their topic. One student in the Digestive and Excretory Group did maintain some previous misunderstandings, keeping her pre-survey score of a four. Just by reading her post-survey response, she would have scored a two. However, through talking to her and

asking a few probing questions a current misconception was revealed. She could not explain with correct scientific understanding how the digestive and excretory systems work together, a big idea for her topic. A similar situation happened with one of the students interviewed from the Earth's Seasons Group. However, she still did improve her understanding partially. Her post-survey response just analyzed alone would have scored her a one. Yet, once she was interviewed she was not able to explain with correct scientific understanding the earth's path around the sun. She was maintaining that the earth travels in an elliptical shape, and that has some affect on the seasons. She did improve her pre-survey score of a three to a four since she could with confidence report that the tilt of the Earth's axis plays a role in the changing of the seasons. However, the interview did reveal more information than just the written post-survey. The other students were able to maintain their written post-survey scores in their interview and were often able to apply their new knowledge to new situations. For example, one student interviewed from the Condensation Group was able to explain how frost forms in the freezer and how that phase change relates to condensation: "The water vapor turns to liquid as it touches the objects in the cold freezer, but immediately the liquid freezes since it is so cold turning it to an icy frost." The more accurate scores revealed by the interviews were taken into account in the post-survey results.

Student work also was analyzed for how students demonstrated scientific accuracy in their written and spoken product. Table 2 reflects the averages the groups achieved based on the five-point scaled rubric.

Table 2. Student Work Averages for Scientific Accuracy

	Average Points Achieved out of 5
All Groups	4.49
Digestive and Excretory	4.22
Color and Light	4.36
Condensation	4.36
Earth's Seasons	5.00

Again, all groups demonstrated decent understanding in their products. However, depending on what group is considered, some more than others. The Earth's Seasons Groups again led the way with all participants getting a five out of five on this aspect of their product. The Digestive and Excretory Group again had the lowest achievement with only an average score of 4.22 out of 5. An example of a piece of work that would have achieved a score of a five can be observed in one of the Condensation Groups. The group's product was a children's book and the written work shows a complete understanding of the water cycle and condensation process:

*“Aaron the Air explained to Wally the Water Droplet that because it was such a hot day Wally went through a phase change called evaporation, ‘This turned you into a gas. I carried you from Larry the Lake to Glen the Glass Beaker because I knew Glen, being so cold, would cool you down enough causing another phase change called condensation which turned you to a liquid again.’ ”*

The above excerpt shows the group understands that condensation is caused by the surrounding water vapor cooling back into a liquid. The group does not maintain

common misconceptions about condensation such as the water droplets come through the solid glass like “sweating”, or up and over the top of the container. One of the Digestive and Excretory Groups achieved a four on the student work. Their brochure recorded:

*“The small intestine breaks down the food mixture so that you can absorb vitamins, minerals, proteins, carbohydrates, and fats. If the small intestine is removed, your body would end up getting infected and you would slowly die. This would happen because your body would not get the essential nutrients that it needs. To remove the small intestine would make it impossible for your body to get nutrients from stomach to the large intestine.”*

The students accurately reported the role of the small intestine. The small intestine does continue to break down nutrients and it is the site where the nutrients are passed to the rest of the body. However, their last sentence is a little unclear in their understanding. The students seem to believe that nutrients still need to travel to the large intestine, when really what should primarily be left is material that will exit the body as waste. Understanding the link between the digestive and excretory systems seems to be lacking. Basing the score solely on their written and spoken presentation, this particular digestive and excretory group achieved a 4, almost a complete understanding. The above examples reflect typical responses with the assigned scores. All groups were analyzed using similar criteria and comparisons.

*Within the teaching strategies used, what do students’ attribute their increased understanding of science concepts?*

The remaining questions on the post-survey helped answer the second research question. Table 3 summarizes the steps of the problem-solving process,

SSCS, and what percentage of students felt they altered their misconception during each particular step.

Table 3. Percentage of Students That Altered Their Misconception During Each Step

	All Groups	Digestive and Excretory	Color and Light	Condensation	Earth's Seasons
Search/Research	42%	56%	29%	40%	58%
Solve/ Discuss	29%	33%	36%	28%	14%
Combination	20%	0%	29%	24%	14%
Create	4%	11%	0%	4%	0%
Share	1%	0%	0%	4%	0%
None	4%	0%	6%	0%	14%

Overall students felt they learned the most during the beginning search phase where researching the topic online and in the given books was the priority. Most found information directly through a source in the search phase. The second highest percentage was the solve phase where students had the opportunity to design a test to prove a given aspect of their topic. The solve phase was also when a lot of discussion took place within the group. For example one student reported on his post-survey that during discussion, ‘I got other ideas from my other group members’ and this seemed to help him. The groups that had the highest solve results were the Color and Light and the Condensation Groups, topics that lent themselves to more lab-like tests. The Digestive and Excretory and Earth’s Seasons Groups used more research-based problem solving. Many students reported that several aspects of the process helped them to alter a misconception, and it was the combination of steps that was the most important. Another student stated in their post-survey, ‘I think it [changing my misconception] happened in between the Search-Solve phase of the experiment

because we did a lot of searching on the topic and then we did our experiment which really cleared things up during the process.” The above statement characterized many of the responses, especially from the Color and Light and Condensation Groups.

The post-survey responses also gave feedback on what students thought of the study’s teaching strategies. Students responded to whether they preferred a guided-inquiry problem-solving process like the one in the study or a more traditional lab, the ‘cookbook lab,’ where the teacher gives them the steps and data to collect. Table 4 depicts the percentage of students overall and in the specific groups who preferred traditional cookbook labs, the problem solving process SSCS, or a combination of both.

Table 4. Percentage of Students that Prefer Cookbook Labs and SSCS Labs

	All Groups	Digestive and Excretory	Color and Light	Condensation	Earth’s Seasons
Cookbook Labs	24%	44%	14%	20%	29%
SSCS Labs	69%	56%	79%	72%	57%
Both	7%	0%	7%	8%	14%

Overall, 69% of students would rather take part in the problem solving process used in this study. Looking at each group more specifically, SSCS is still preferred. Many reasons were stated for this. The most common reasons were: the freedom to be creative, learning being more meaningful since the students had to do it themselves, and the enjoyment of working in a group versus having to listen to the teacher talk. A typical response from one student was: “I like creating our own labs because it involves us more and we don’t have to follow directions step by step that

you give us.” However, the Digestive and Excretory and Earth’s Seasons Groups did have a higher percentage that would rather have done a cookbook lab. The students cited several reasons when explaining their response. Many struggled with coming up with a testable question for their lab or not knowing if they were “right” throughout the lab. For example, one Earth’s Seasons student wrote: “I would rather do a lab that the teacher gives us the steps to perform. It’s more organized this way, and you already know what to do because you just read and follow the teacher’s directions.” With a cookbook lab the students were thinking they could more easily stay on track with a set goal. Still a few students reported they would prefer both types of labs, meaning they loved the freedom, but would love a little more guidance from the teacher. A typical response in this case was: “I would prefer both so you can learn more interesting ideas from the teacher and you can make your own ideas and check to see if you’re right or wrong.” While 7% of students desired a combination of both lab methods, overall SSCS labs were the favorite.

The group interview echoed the post-survey results. All four students talked about liking the freedom of the project and the amount they learned. The students felt that even looking up the information for themselves was more meaningful, and then discussing it with their group members really made it more convincing to them. One student said: “I feel like I learned it because I had to look up the information for myself and you like had to explain it to your group members. Then you had to tell them what it meant, but they didn’t believe me so we had to keep investigating.” The process that resulted, constant questioning and discussing, turned out to be very



successful at allowing each group member to learn and have a full understanding of the topic. The students agreed that this type of learning was more “convincing” than just having the teacher tell them the facts. One student also stated: “If you have a question you can always ask them [someone in your group] instead of turning to the teacher first.” She saw turning to group members as a positive because it made them be more independent learners. Negatives reported involved group dynamics and struggling if the group did not have a solid leader or had people who “slacked off?”

Even though fewer students reported in Table 3 that the Create Phase was necessary in altering their misconception, the interviewed group unanimously reported that they felt it was a necessary step. They enjoyed the choices they had in making the product and felt the product summed up all their work for them. They also felt the Share Phase was helpful and liked hearing about what other groups had been studying during the time.

## Chapter 5: Conclusions and Recommendations

The goal of the study was to determine whether teaching strategies alter students’ misconceptions in science. Results of the described study suggest that this goal was accomplished to an extent. Identification of the students’ misconceptions, grouping the students, and then guiding them through a student-centered process of inquiry and problem solving seems to alter students’ misconceptions.

Just like in the Chang & Barufaldi (1999) study the open ended pre-survey served its purpose of eliciting the students’ misconceptions. The open-ended questions allowed the students to elaborate on everything they knew, especially when

they added drawings. However, there were some weaknesses in the survey, students were still concerned with getting the “right answer” and would be sure to write the one key word they remembered learning. It was difficult to know if the students really understood the particular word. For example, many students on the pre-survey question, “Explain what causes a cold drink to have water droplets on it during a hot day. Where do the water droplets come from? What causes them?” would be sure to say the word “condensation,” but would not necessarily explain what the word meant. Written answers only tell the researcher so much. Chang & Barufaldi (1999) recommended that interviewing the students would help alleviate this problem, and the study took that into consideration. However, as one can imagine sometimes it is not feasible to interview all students. In this study, a selection of students were interviewed after the completion of the post-survey.

There were many factors that influenced the learning process. One of the largest factors that was not recited in the prior research was the role of personal interactions between group members. It is one thing to place students into groups solely based on the pre-survey results, but it is much more difficult to also consider who will work well with whom. Many of the struggles with the study rooted with students having problems working with others. When students gave feedback in the post-survey and in interviews, one of the largest disadvantages attributed to the process was dealing with people that were difficult to work with. One student interviewed suggested: “Let us pick the people in our group; that way we would work more cooperatively and get more accomplished.” However, that would defeat the

purpose of this study as students needed to be in groups of their particular misconception and not just with people they like. Prior research has emphasized the importance of working in a group to facilitate the learning process (Jarvis & McKeon, 2005). However, more research is necessary to look at the interpersonal relationships between group members and how the relationships affect the learning. Considering group dynamics is crucial when doing intensive group work, as was the case in the study.

When given the opportunity, students did grasp the chance to learn in the student-centered environment. Teachers often find it difficult to relinquish control of their classroom. Yet, research has shown a student-centered environment to be effective at increasing student learning (Burrowes, 2003; Udovic et.al., 2002). The study described also found the student-centered environment a productive technique as 49% of the participants fully altered their misconception. Furthermore, 82% improved their understanding of their misconception topic. However, the Digestive and Excretory Group did not seem to alter their misconception as much. Only 11% of the group reached complete understanding and 33% improved their understanding on their post-survey. When looking at what they actually studied during the student-centered process there may be an explanation for the low results. The Digestive and Excretory Groups researched questions like: "What happens to your body if you take out one of the organs of the systems? How do energy drinks affect your body- what are the side effects of the ingredients and why do they make you 'crash'? Do other animals have digestive and excretory systems- why or why not?" The nature of the

process of SSCS gave the students freedom to explore an aspect of their topic that did have personal interest to them. However, it also may have meant that they were not directly addressing their misconception. The research said student-centered inquiry based activities does alter misconceptions (Chang & Barufaldi, 1999; Weaver, 1998). Yet, research also says in order to alter misconceptions the learning must be based directly on the faulty idea (Uzuntiryaki & Geban, 2005). The other groups did have testable questions more directly related to their misconceptions. For example, one Color and Light Group actually sat in the darkest room they could possibly find and looked at a red apple. They realized they could not see it, their eyes would not adjust, and the room was darker than any they had ever been in. The apple test directly addressed a personal misconception. Not exactly confronting the misconception in the SSCS process may be a discrepancy that the study brought to the surface. Does the freedom allow for students truly to be focused on the misconception, or does it just get altered in a round-a-bout way by chance?

While the Digestive and Excretory Group had the lowest percentages in altering their misconceptions, the Earth's Seasons Group had the highest percentages. The Earth's Seasons Groups did focus first on answering the question: "Why do we have seasons and what causes them?" Once the students felt they reached a solid understanding in this area, they went on to extend their research to include: "How are the tides and seasons related (or are they)? Why does water go to each side of the earth on a neap tide? What do the seasons have to do with global warming? Why is the earth tilted? Why does the earth revolve around the sun? Do other planets have

seasons and why?' When asked the post-survey question the Earth's Seasons Groups seemed to have a solid understanding of the topic because they were directly investigating it. The students were directly addressing their misconception, unlike the Digestive and Excretory Groups. However, when considering the information gathered during the interviews some Earth's Seasons students still did not have a depth of knowledge. Out of the two students interviewed one seemed to have a thorough understanding, yet the other could only recite the facts about seasons, she really did not understand them. For example, she could recite that the seasons are caused by the Earth's tilt, a good answer by itself. Yet, when asked to explain the path of the Earth around the Sun and if this relates to the seasons, she still was unsure, saying she saw diagrams that still made her think the pathway was elliptical. The student's belief in an elliptical pathway seems to be a very common phenomenon (PUP, 1989). Many students in the study could write the right words for the right answer, but when probed deeper, they did not really understand.

The observation of students not truly understanding gives rise to two recommendations. First, as educators we must carefully examine our teaching tools and techniques in the case of accidentally reinforcing misconceptions. The common diagram of the Earth's path around the sun always seems to look elliptical in an effort to make the drawing two-dimensional. Yet, the eclipse is misrepresenting the true path and reinforcing our student's misconceptions. Just as Jarvin & McKeon (2005) would agree the educator must have a deep understanding of the topic in order to recognize these common discrepancies. Also, as suggested by Michael (2002) and

Morrison & Lederman (1998) providing teachers with a list of common student misconceptions in the content before beginning to teach would be beneficial. A list would allow the teacher to know what thinking to be aware of. Second, in order to truly understand what your students know, interviewing seems to be the most precise method. The results were much more accurate for the seven students who were interviewed because they either better explained their answers or there was a higher confidence level in their original written answer. In the Chang & Barufaldi (1999) study they recommended performing student interviews for a truer assessment of student learning. It is unfortunate that it seems impossible to sit down with fifty-five participants. Yet if limited to five minutes, interviewing is a valuable way to truly understand how each student is thinking (Henry, 2006). Some techniques recommended by Henry (2006) include putting away your “teacher role” and responding neutrally to any student responses. If the educator grimaces or is too encouraging the student may change their answer or become confused. The goal of the interview is to get the students’ true thoughts, not to fix their misconceptions right there.

The scores on the student work also reinforced that misconceptions were altered with an overall score of 4.49 out of 5. The lower percentage of students completely altering their misconceptions in the Digestive and Excretory Group were reflected in the student work as well with an average of 4.22. The lower score again can be attributed to the Digestive and Excretory Groups not researching a question directly related to their misconception. At the same time, using the five-point scale

made it very difficult to judge the work. In general the groups may not have created a product directly addressing their misconceptions so the scale was really looking at any fact they recorded or spoke, and not necessarily a corrected misconception. For this reason, the student work score may not be an accurate data piece in measuring if misconceptions were altered.

As for where the students attributed their learning to take place, the search phase of the process was the most popular response. During the search phase, the students researched their topic in the various resources available. The students used a chart worksheet to organize their findings and record how they knew information related to their original thoughts (Appendix). Many students predicted and then changed their ideas once they investigated the topic the first time. For others, their notes indicate they found information that reinforced their original ideas or corrected one wrong aspect. A Digestive and Excretory Group member wrote on his cart summary: "The info. [he found] taught me more about both digestion and excretion. For example the small intestines continue to breakdown foods. I did not know this. And I also did not know the lungs were part of the excretory system." Several students said the information they found made them think deeper about their misconception. Many of the Condensation Groups realized condensation doesn't just happen on a glass; it is involved with weather too. One student wrote: "Condensation plays a rather large part in rain (precipitation). In fact, it is one of the first steps in this because the colder it gets it goes from a gas to a liquid." Having the students complete the research on their own truly makes the work meaningful (Deters, 2005).

Much of the literature predicted that the actual hands-on steps of the process, also known as the solve step, would elicit the most altering of misconceptions (Deters, 2005). The solve step was reported as second most effective in all but the Color and Light Group. What is interesting to note, however, is that the topics that lent themselves more to laboratory work, the Color and Light and the Condensation Groups, were the two groups that also had the highest percentage in the solve steps. Since the Digestive and Excretory and Earth's Seasons Groups were more difficult to test with an eighth grade classroom's resources, these groups struggled with figuring out a question to solve. Perhaps that is why they felt more successful in learning during the search phase. The Color and Light and Condensation Groups both had various options for testable activities using flashlights, prisms, cups, and water. Because they had all of the resources available, the solve phase may have worked better for them.

Similarly to Jarvis and McKeon's (2005) study, many students in their post survey also emphasized the importance of discussing facts they were learning with their group. A discussion comment was considered to be under the solve step even though discussion could have taken place at any time. Guided discussion is key because students could also get stuck emphasizing each other's misconceptions. Jarvin and McKeon (2005) stress the importance of having the educator in close contact with each group, however with so many participants this was practically impossible. One student did admit in an interview that she thought she understood condensation, but after talking to her group at the start of the investigation she



became more confused. Her group members were convincing her that the water droplets came from up and over the top of the glass, a huge misconception. Luckily, the teacher was monitoring the condensation discussion and encouraged the group to complete a lab where the students observed whether condensation formed on bottles with tops and bottles without tops. The guiding technique done by the teacher was modeled in the study by Li et.al., 2006. Furtak (2006) says to be neutral and not give answers outright in inquiry to allow students to receive the true learning experience. Since having a top on the bottle did not influence whether condensation formed or not, a new discussion in the group helped them attain a true understanding of condensation. By the end of the process the student in question did score a one on the post-survey, and did alter her misconception.

The students' opinions of the SSCS process, on average, were very positive, reinforcing previous studies results on students' opinions of student-centered inquiry activities (Deters, 2005). However, the Digestive and Excretory and Earth's Seasons Groups did have lower percentages preferring SSCS. Again, since the Digestive and Excretory and Earth's Seasons Groups had a more difficult topic to explore in a lab situation, the groups may have simply struggled with the solve part of the process. In fact, when looking at specific surveys many students cited that they had a difficult time coming up with questions or a test on the research-minded topics.

Some of the students also reported they had a difficult time not knowing if they were doing the 'right' thing. Deters also observed this fear in her 2005 study. With the inquiry approach some students had a fear of being wrong. Perhaps, this

aspect of the study recommends that inquiry learning needs to be practiced in order for all students to truly benefit and be comfortable. With the testing emphasis in our school systems, learning that it can be beneficial to make mistakes can sometimes be difficult. Some students wanted to have the freedom to choose their own topic completely, while still others wanted more direction and reinforcement along the way. As Mastropieri, Scruggs & Butcher (1997) and Tomlinson (2001) reminded us, students have different learning styles. Differentiation by readiness, or what the students know, is important. However, a student's learning style is important as well. Not placing a focus on each student's learning style may have been an oversight in the study. Some students are better at being inquisitive by nature. Some are more internally motivated to learn just for the sake of learning. The desire to ask questions may be a learned behavior that is fostered in the home, and is necessary for the inquiry process.

The students also stated in the interviews and post-surveys that all steps in the SSCS process were necessary. Through observation of the students working, it seemed the create and share phases might be redundant. The students seemed to be more distractible and were just recopying prior notes for the second or third time. The products seemed to have few guidelines so students were only working to their motivation and not a set expectation. The presentation to follow lacked in similar areas. Yet, when the students were asked about the create phase they appreciated the freedom of choice in the products. The students felt it was a necessary way to conclude the product and it did require them to summarize their learning of the past

two weeks. The students also enjoyed hearing about what other groups had studied. There may be several explanations to the discrepancy of the researcher's observations and the student's opinions. It should be noted that the study took place at the end of a school year and the students were in their normal hyped state. The end of the year is a difficult time to focus, let alone take part in a project that requires a high level of independent thinking and work. Many students did report never having this much freedom of choice over their studies or a product before. Perhaps it would be necessary to determine a few more expectations in the create and share phases instead of completely eliminating them. The students did accomplish a substantial amount of learning, given the circumstances. According to the students, all aspects of the SSCS process were not only necessary, but also enjoyable.

There is still much to be learned in the topic of teaching strategies altering students' misconceptions in science. Further research should consider several areas of study. For example: how group dynamics and the relationship of the students in the group affect altering misconceptions. Another is how misconceptions are altered when comparing the freedom to search in all areas of the misconception topic, to directly focusing on addressing the particular misconception. Lastly, the learning style of the student should be studied. If students are unfamiliar with the inquiry style of learning, they may need to be taught how to use it, which might lead to more success.

The use of a student-centered inquiry based teaching approach can be successful, as described in the study. Yet, there is still no one perfect fix.

Misconceptions are hard to change (Bahar, 2003; Ridgeway & Dunston, 2000) and one strategy will not work with every student. As educators, we must identify our students' misconceptions and do everything we can to help alter them. It is the educator's responsibility to be aware of common misconceptions in our teaching tools. Professional educators need to have a thorough understanding of the topic, so as not to reinforce misconceptions. Teachers must seek to understand what our students are truly thinking by conducting careful interviews. By guiding our students in discussions and the SSCS process, misconceptions can be altered. If students can make progress in altering their own misconceptions, they will be better educated, better learners, and above all, better citizens.

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Appendix

**Investigating Our Misconception:  
SEARCH Phase Continued:**

Group Member filling out this paper: \_\_\_\_\_

To be filled out as you continue your investigation on the computer, books, videos etc. and are trying to determine a possible question to research/ test/ solve/ prove.

<b>Interesting facts I found out about my topic:</b>	<b>My reaction:</b> How does this change my personal knowledge of the topic? Could I use this information to help me form a question I could test or prove? What website am I using in case I need to find it again?

**SUMMARY:**

Place a star next to the boxes above that contain a question that you would like to research in your group.

How did the information you found today change your initial knowledge of your topic? What do you know now?