CONSIDERATIONS AND STRATEGIES TO PROMOTE CONCEPTUAL CHANGE IN SCIENCE AND MATH

by

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Abstract

This paper investigates effective strategies for teachers to assist students in challenging their conceptions in topics and concepts of math and science and of their epistemology of science itself. This includes research throughout the educational experience from elementary through pre service teacher education. No single strategy proved effective for any group therefore it can be concluded that the implementation of multiple strategies for the same concept or topic. The use of multiple strategies could allow for more students to gain conceptual change in addition to the possibility of allowance for deeper understanding in students who found previous strategies effective. In addition implications of particular strategies proved consistently ineffective and even made conceptual change more difficult for educators to establish. For instance, the use of rote memorization without the implementation of pedagogical tools that included complex thinking skills such as those outlined by Blooms Taxonomy continuously proved to be an ineffective strategy for addressing misconceptions. In addition studies also indicated metacognition as effective higher order thinking strategy that promoted conceptual change.

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Chapter One: Introduction

Statement of Research Question

This paper investigates effective strategies for teachers to assist students in challenging their conceptions in topics and concepts of math and science and of their epistemology of science itself. This includes research throughout the educational experience from elementary through pre service teacher education.

A conceptual framework is individual to each person and is based on their interpretation of experience and reaction to those experiences in attempts to create a mental model or an intuitive map of what is truth and thereby what truths to live by (Fischbein & Schnarch, 1997; Piaget, 1963).

Problems arise, notably in math and science, when general rules of logic or intuitions that individuals form come up against “non intuitive” concepts and patterns. It is at this point that misconceptions or alternative conceptions are formed that stray away from the commonly recognized standard of thought (Fischbein & Schnarch, 1997; Beeth & Hewson, 1997). A conceptual framework based on a misconception can lead to a series of misconceptions and hinder further understanding of subsequent concepts and topics (Hennessey 1999). As the study of math and science are closely related, I have chosen both for this investigation.

Statement of Rationale

Some students' perceptions of biology and other sciences consist of facts; body parts, basic functions and explosions from sodium. However the science students often experience is more than facts and history. Science can include intriguing conversation and problem solving; labs can be more than a set of instructions with a correct end result. For students in the United States, science class before advanced courses in college can generally lack the challenge of inquiry. Science class without this challenge could in some students lead to a lack of motivation. In addition, it can create negative epistemologies of science based on frustration and boredom that intense memorization tends to be associated with. Adolescence, when individuals are questioning the world around them and can tend toward rebelling from authority, seems to be the perfect time to reinforce inquiry with a logic structure based on different than most forms of argument taught culturally and academically. It encourages the questioning of your own ideas closely linked to the practice of metacognition, thinking about thinking.

This process can be so different it can create frustration in students who have become successful in the traditional structure of science based on memorization of facts and procedures. Rimor, Reingold, and Kalay (2003) expressed such findings in the development of their rubric for student metacognition. Anderson (2002) discussed one important aspect of metacognition as increased capability of students to determine the direction their learning needs to take:

> The use of metacognitive strategies ignites one's thinking and can lead to more profound learning and improved performance, especially among learners who are struggling. Understanding and controlling cognitive processes may be one of the most essential skills. (p. 1)

This frustration in students can be an obstacle to necessary change in curriculum and pedagogical practices. Understanding seemingly ancillary topics such as metacognition could have impacts on students' epistemology of science and create classroom situations that may be interpreted as a teaching strategy as ineffective. Several papers selected for chapter three were included because they considered such possibilities in the research design.

One of the major concepts in biology, the study of evolution, has become a controversial concept in many school districts in the United States. Students may not understand the concept and thus develop negative epistemologies of science. This has been considered detrimental to science education because evolution maintains a position of unifying the scientific framework of the natural world. Misconceptions and preconceptions of evolution can develop from personal and political memes. Misconceptions of evolution alone could be a deal breaker for many students in the pursuit of participation in science because misconceptions of evolution can create a culturally and spiritually inhospitable environment (Tuhiwai, 1999).

Another area of concern in science education for inclusion of all students to prevent the creation of negative epistemologies of science. Historical science figures commonly represented in text may contribute to the formation of negative epistemologies because they generally only include western white male figures. Other than the rare female science teachers, most of the scientists in history as well as in current research presented in science curricula are men, many of whom are white. This could create a jaded perspective of ability to be successful in science for any students who do not identify by race and geneder with the figures represented(Johnson, 2001). At a developmental time when identity is a focus of individuals, adolescents may feel as though science was beyond their grasp, a field that would be inherently difficult and unwelcoming for women and children of color (Phinney, 1989). The white men used as the majority representatives of scientists in textbooks could account for the development of epistemologies of science as being too hard and too far out of reach for many students (Loewen, 1996). Loewen (1996) described aspects of this phenomenon as heroification:

> about heroification, a degenerative process (much like calcification) that makes people over into heroes. Through this process, our educational media turn flesh-and-blood individuals into pious,

> perfect creatures without conflicts, pain, credibility, or human interest. (p.19)

The aforementioned possibilities of development of a negative epistemology of science, resistance of the possibility of success in science, and prevention of understanding of concepts and topics of science because of assumed preconceptions and misconceptions influenced the direction of this paper toward the investigation of how science teachers could be more effective in assisting students to challenge their conceptions and frameworks in regards to topics and concepts of science and math as well as their personal epistemologies of science. It was presupposed that through an investigation of concept formation, misconceptions, worldviews, and conceptual change through various cultures and educational systems could create more effective educators and students, by investigation of effective strategies for evaluating misconceptions and promoting conceptual change.

Limitations

This study is limited by cultural, racial and socio-economic range of subjects who took part in the studies in chapter three. In addition much of the research took place in the Midwest of the United States, Israel, and Korea. Demographically heterogeneous groupings were not explored to the extent that it could be direct evidence of cross-cultural effectiveness in the United States. In addition, much of the research presented was conducted prior to 2000 and thus may lack consideration for cultural differences in generation and common population in schools. In addition to possible differences that go unaccounted for, researchers in articles prior to the law's enactment could not have observed the possible effects to classrooms in the United States initiated by the No Child Left Behind Act of 2001.

Limitations of this study include the delicate ethics involved with any human research especially with vulnerable populations, for this study namely children and adolescents. Ethically delicate matters that may limit a study include gaining consent from parents for participation of their students, the loss of use of control groups, ethical restriction of extreme or potentially harmful treatments, and ethical restriction of study control over possible variables. Attainment of consent from parents for analysis of student work and observation of their children can be tricky and difficult. It is for this reason that particular cultural populations may be amenable or resistant to their children being part of a research study. For instance, indigenous groups that historically have been mistreated by social or scientific investigation may be resistant to give consent (Tuhiwai, 1999). Due to ethical and time constraints of researchers, educational studies tend toward a case-study format. Control groups outside of the comparison of groups of students prior to the treatment year are difficult to come by because it would be unethical to restrict a potentially helpful treatment on a group of students. In addition, research with human subjects ethically restricts and complicates the researchers' ability to restrict possible variables.

In addition to ethical restraints, there may exist environmental and cultural variances unaccounted for in research design. This includes and does not limit to the following examples: populations of students that may leave or enter a classroom environment during the study, variation of lesson execution by educators, variation in classroom management or other pedagogical factors, and classroom environment. Other limitations include characteristics of time constraints of the classroom for interviews and analysis.

Chapter four attempts to take the afore mentioned limitations of political, socioeconomic, ethical and other limitations to the use of human subjects into account in discussion of possible classroom implications and suggestions for further research.

In addition, chapter three narratives that contain such limitations are noted in the final paragraph for each research paper. The narratives for each investigation reviewed also include limitations specific to the research design, population, execution and analysis.

Other limitations include data and background information not included for evaluation and analysis.

Definitions

Throughout this paper, misconceptions, alternative conceptions, and preconceptions are utilized interchangeably. The basic definition for all three is conceptions of topic and concepts in science and math that do not follow those accepted by the intellectual communities for each perceptively. A notable variance between preconceptions and alternative conceptions or misconceptions lies in that preconceptions generally are related to ideas or patterns of ideas that individuals have before any instruction is provided in a specific topic or concept. In general, this can range from various ideas about the workings of molecules to what science is and how it is performed, or here fore described as an epistemology of science.

Intuitive misconceptions are discussed in the first topic section of chapter three, in particular the subsection titled *Maturation of Misconceptions*. Intuitive misconceptions are common misconceptions formed by most groups of people tested by the use of common logic or the use of logic that is effective for other concepts. The formation of such misconceptions commonality is due to the intuitive logic that was used proved successful for many other problem solving situations.

Definitions utilized in only specific papers will be defined as they are used.

Chapter Two: Historical Background

Conceptual Formation and Change

The groundbreaking research in conceptual change generally is accredited to Piaget and Inhelder during the 1950s and 1960s. Piaget, and later along with Inhelder (1958), initiated the theoretical frame of learning as developmental. Piaget and Inhelder (1958) made a theoretical description of conceptual frameworks and cognitive development that ranged from concrete operational thought categorized by a fact-based epistemology to the more complex formal operational thought such as the practice of metacognition.

After the work done by Piaget and Inhelder (1958), two theoretical movements arose, Piagetian such as Chandler (1987) and neo-Piagetian such as King and Kitchener (1994). Both Piagetian and neo-Piagetian developmental epistemologies maintained that intellectual development, as laid out by Piaget and Inhelder, from concrete to formal operational was based on age, and therefore the fact-based curriculum that Piaget first observed was continued under the assumption that it was developmentally appropriate. However, others such as Hennessey (1997), Carey (1985), and Metz (1995) began to release research that exhibited that even young children in elementary school could achieve academically through use of metacognition and engagement in inquiry and a learning community that was thought to be possible only for older students in adolescence.

In addition to the work that revealed deeper thought process capabilities of the young, some of the same research such as that done by Hennessey (1997) and colleagues along with Beeth (1997, 1999, 2000) discovered that a student's epistemology of science was negatively affected and that misconceptions in science concepts and topics increased when students were denied early science education or instruction based on conceptual change and formative assessment of misconceptions.

Formation of Negative Epistemologies of Science: Culture and Practice

As reported previously, a conceptual framework is developed throughout a person's lifetime, and therefore various experiences including those outside of a classroom have an effect on an individual's framework. The culture of a person's family, community, country and even world events can have a profound effect on how they view the world and consequently what their epistemology of science is (Rogoff, 2003; Smith, Maclin, Houghton, & Hennessy, 2000).

Products of science can of course be utilized by people in various ways and with a range of ethical responsibility. World events such as wars, genocide and even medical research have been reasons for many people to think negatively about science and develop to the point of the development of negative epistemologies of science (Deutsch, 1979). Deutsch revealed that throughout recorded history, technology that has been developed through science has been both revered and demonized based on the technology's cultural effects. Even the weaver's loom became a controversial technology in France because it required different plant material (Deutsch, 1979). This meant that the crops farmers had relied on to fetch a sale for generations of an economic system had to change their infrastructure to accommodate the new market of plants used as a weaving fiber (Deutsch, 1979). And rightly so; a change in crops meant an uncertain future for a family's survival. Controversy over the use of technology that has included when, where and whether the technology or knowledge should be used at all is not a new topic nor is it one that has ceased. How people survive and are successful exists within a particular system of actions, events and thought processes (Rogoff, 2003). The addition of what might be perceived by some to be a small change can alter the entire structure of that system (Senge, 2006). Therefore ideas of the natural world whether it be the functions and systems that exist or even the existence that something is or is not there could alter the success and livelihood of an individual, family, community, region and the human population as a whole (Deutsch, 1979). Examples include food storage; the ability to do so and its continued development have changed the habits and structures of communities (Kantner, 2004). Examples of this include the development of corn agriculture and storage among the Ancient Puebloans in the Southwest of the United States and the revealed existence of microbes and the development of the field of microbiology on medical practices and food storage (Kantner, 2004; Magnus, 1908). There was a time in Western medicine when hand washing by a physician was considered ridiculous by the medical community (Magnus, 1908). In addition to some of the smaller changes to communities, the previously mentioned effects of technology that enhanced war and medical research done under poor ethical pretenses also have contributed to mistrust of science (Deutsch, 1979). Nuclear war, unconsented medication and purposeful unconsented infection are a few examples of why entire cultures of people have developed mistrust in science and subsequently of related education as destructive and unethical.

In addition to new ideas and technologies being developed through science, conflicting reasons for the same practice also have caused negative cultural discourse. For example, a hand washing by a medical practitioner before and after a client visit is practiced through many professions from many healing arts with a myriad of reasons for the practice (Rechelbacher, 1999). For instance, some ayurvedic massage therapists have been instructed in the practice to wash hands between clients as to not cause harmful energy transfers between clients and between clients and themselves (Rechelbacher, 1999). Other practices from faith-based healers have been found to have benefits from a scientific medical perspective. These findings can create a richer body of knowledge around the practice, but they can also have been perceived and communicated in patronizing and otherwise negative manners not to mention that culturally based nonscientific knowledge and practices can create an imposing environment (Tuhiwai, 1999).

In some cases, not only the products of science, knowledge and technology alike, but also the acquisition of that knowledge have been reasons for people to develop mistrust and negative epistemologies of science (Tuhiwai, 1999). Tuhiwai described the mistreatment of various indigenous peoples colonized by western countries and focused on the Maori people of New Zealand. As analyzed by Tuhiwai, people who had been colonized although not acknowledged as such by the countries any longer are still colonized and treated as such. This includes the historical and some current practices of acquisition of knowledge of the natural world between western-trained scientists and indigenous and other colonized and imperialized peoples. In many cases, the intellectual property indigenous peoples have acquired throughout generations is for all purposes stolen, according to Tuhiwai's investigations. She describes that the acquisition of knowledge in such instances is not part of an ongoing equal relationship between people and communities, but rather one where the system of privilege is continued (Johnson, 2001). Instances such as these have lead to a mistrust of and misconceptions about science throughout many communities and cultures (Gill & Levidow, 1987; Tuhiwai, 1999).

Formation of Negative Epistemologies of Science: The Classroom

In addition to the practice of science, the science classroom and classrooms in general have been noted to create a hostile environment based on privileged systems that can lead to negative epistemologies of science and epistemologies based on misconceptions (Gill & Levidow, 1987; Johnson, 1999; Zinn, 2003). Social systems that contain a privilege structure in the United States have been historically documented to also occur and in fact are credited to some of the infrastructure of the public school system (Spring, 2007). Many colonized peoples have historically endured deculturalizing schooling, including in the United States. Spring (2007), Tuhiwai (1999) and Johnson (1999) analyzed educational systems at the times of their perspective books to still maintain racist, sexist and other forms of biased privilege-based systems. These practices in educational systems reward the norms of behavior and other ways of being of the socially privileged group, and punish or ignore others (Johnson, 1999; Spring, 2007).

Some individuals have gone so far as to attribute systems of dominants and subordinates as an innate system 'supported' by science instead recognition of the system to the creation and support of the tiered power and privilege structure (Gill and Levidow, 1987; Johnson, 1999; Spring 2007). This is evident even in behaviors and expectations of instructors that a particular race or gender of student will be inherently successful and others will struggle (Gill and Levidow, 1987; Johnson, 1999).

In addition, a challenge to improve the epistemologies of science of the communities that have been oppressed or otherwise mistrust science is that science is seen by many scientists, educators and researchers alike to be politically and culturally neutral (Gill & Levidow, 1987). The communities and individuals that have been affected negatively by technology, ideas, research, and educational systems and practices do not see science as neutral, however, but rather as part if not the cause of harmful outcomes historical and current.

For instance, in science there are questions about how funds for research can drive specific findings; specific examples in the United States are pharmaceutical, fossil fuel and nutritional research (Hazen & Winokur, 1997). Funding for what is meant to be scientific research can alter not only the findings that are reported, but also what findings are not reported. For instance, a finding such as a detrimental side effect to a drug is not likely to be reported if the would-be reporter's job depends on the drug doing well. There are, of course, governmental agencies as well as consumer groups set up to prevent and retroactively correct such unfortunate happenings, but they are not always effective (Hazen & Winokur). There are some institutional laws that actually penalize for negative findings released about a product.

The science content taught in public schools also tends to hallmark the western white male contributions to science and does not include contributions made by people and communities of countless cultures, races and genders as outlined by Conner (2005) in *A People's History of Science* (Gil & Levidow, 1987) and discussed in the rationale in chapter 1. Representation or the lack thereof is one of the implicit ways that social systems that privilege particular groups continue to proliferate in a culture (Conner, 2005; Johnson, 1999). Math, science and science education are not immune to the structure of the social system that they are performed. Therefore where the goal may be neutrality, it is important to recognize where and how bias enters science and math and how as a field it can be moved toward inclusiveness to grow as a body of knowledge and prevent negative misconceptions and negative epistemologies (Gill & Levidow, 1987). The overview of research to follow in chapter three is an attempt to investigate what strategies have been effective and which have not in the promotion of conceptual change around misconceptions of concepts and topics in math and science as well as epistemologies of science.

Chapter Three: Integrative Review of Literature

Chapter one identified and discussed the research question as and investigation to uncover effective strategies for the promotion of conceptual change in students, the rational behind why it is a pertinent question for the profession as to promote conceptual learning and positive epistemologies in science. In addition chapter one examined limitations of research performed in these field of study and in particular research performed with human subjects. Definitions of pertinent words and phrases or with common alternative meanings were also described.

Chapter two described a brief history of the research performed to understand the formation of ideas, of common scientific and mathematical pedagogical practices in the United States, as well as biased practices in science and science and math education that have excluded certain groups or otherwise been the catalyst of negative epistemologies of math and science. Chapter three will present more current research that reveal effective and non effective strategies as well as the nature of preconceptions, misconceptions, and conceptual change. Chapter four will synthesize the material from chapters one, two, and three into final reflections of this investigative paper.

The Nature of Preconceptions, Misconceptions, and Conceptual Change

The following two papers describe some factors that may influence the effectiveness of strategies aimed to address misconceptions. These were included to provide educators with information to assist the effectiveness of presentation and execution of the strategies discussed in the second topic section. The following subsections, *Links Between Historical and Conceptual Change, Developmental Stages of Conceptual Change, Maturation of Misconceptions,* and *Preconceptions That Inhibit Conceptual Change*, focused on research aimed to identify common aspects of misconceptions and the nature of misconceptions.

As with many explorations, sometimes the most valuable information gained differed from what was intended. The researchers intended to compare the effectiveness of examples and analogies to assist students in comprehension of difficult concepts in a physics classroom. What they found was that there was further variance than simply examples and analogies in the design and function within the lesson the explanatory tools were used.

Brown (1992) conducted evaluation of the effectiveness of various types of examples and various types of implementations and analogies to alleviate students' misconceptions in physics. In addition, Brown maintained a second goal to challenge pedagogy based on only teaching by example.

High school chemistry students (n = 21) pre physics instruction volunteered to be interviewed and receive one of two sets of examples and analogies in the hopes to challenge their misconceptions. The main task of the authors was to evaluate the effectiveness of instruction by example versus instruction with help of analogies.

The author concluded that for both examples and analogies to be effective they must be understandable and believable to the subject by explicit development of an analogous example and models that the subjects can visualize to mechanistic explanations, analogies, to phenomena. As was predicted by the author, presentation of phenomena with supporting examples did not exhibit significant conceptual change. The investigation contained detailed examples of the common misconceptions and attempted conceptual change by treatments. The findings of believable examples linked to higher success rates ($p<0.0001$) did not surprise Brown, however more successful examples did not prove alone to be as successful at the promotion of conceptual change in all circumstances as when educators explicitly developed relationships between the example or analogy and the actual phenomena. Information gathered from the qualitative interviews supported the quantitative findings. The interviews revealed that subjects reverted to intuitive misconceptions when the relationships between analogy or example and the actual phenomena was not explicitly developed or explained. This is relevant to the effectiveness of strategies for creation of conceptual change by the established need for believable and explicit relationships between examples or analogies and actual phenomena. This knowledge may help educators be more effective especially for students of cultures varied from their own and thereby address some of the concerns of negative epistemologies discussed in chapter one and two.

Brown utilized pre-tests for only three out of the five questions, therefore Brown should have reported the results for the last two questions as inconclusive. However the quantitative findings listed the results from the post-test as significant in the results table ($p < 0.01$, $p < 0.05$). The results from one question did not show significant differences. Two questions analyzed significant ($p < .01$), which left the author with only 40 percent of questions left of an already small sample set of five questions. The subject selection process leans toward a lack of heterogeneous sampling due to the nature of the volunteer process. These design critiques indicate a possible sampling bias and therefore make it difficult to asertain the effectivness of the treatment across various demographics.

In addition to the previous findings of design requirements for strategies such as an analogy to be effective through the pedagogical development of explicit relationships to phenomena, the following authors indicated additional environmental influences as well as cultural ideas held by the subjects altered the effectiveness of particular strategies. These indicated that although in the second section patterns of effective pedagogy are revealed, individual and cultural variance of subjects may require augmentation and further investigation of pedagogical practice and instructional design in different groups.

Barlia and Beeth (1999) conducted a study of motivational factors for conceptual change. Subjects were twelfth-grade students (n = 11) in a traditional calculus-based physics class and their teacher. In addition to motivational factors, the study intended to investigate patterns of motivation and engagement as well as the determination of motivational profiles for each subject in attempt to understand how much variation might be common between individuals.

Data was collected from self-reported responses and the Motivated Strategies of Learning Questionnaire (MSLQ), in addition to structured interviews with students, and a cross-case analysis for the entire group was performed.

The authors reported that individual differences were present for every student, but that task value and control beliefs are most important for most students in addition to factors not in the analysis such as teacher personality. Barlia and Beeth (1999) noted additionally that these findings imply the importance of educators' expression of enthusiasm for the subject and focus on more than rote memorization of facts to increase value of task importance to students.

The subjects of this study, as with the previous study, belonged to a higher-level science class. The use of these subjects may limit how applicable the results are in a general science classroom as well as classrooms of younger students. High school seniors in a class generally selected by college-bound science majors implies the possibility of bias in the outcome of the study as compared with general science class populations and age. The outcomes of this study might have been biased because most of these courses tend to be populated by white males of middle- and upper-class socioeconomic status. These differences may express themselves in pedagogy and class environment expectations and motivation for the class in general, which may directly affect the outcome of the research questions.

The previous two papers described the importance of the comprehension of possible variance in what strategies are found effective for the evaluation of misconceptions and the promotion of conceptual change. The subsections that follow address commonalities discovered in the nature of misconceptions as well as preconceptions that inhibit conceptual change.

Research Linking Historical and Developmental Conceptual Change

Although this section contains only one paper it indicates a larger pattern in conceptual change. The research below indicates a pattern between historical development of concepts and conceptual change as commonly observed through the intellectual development of a concept seen among individuals.

Griffiths and Preston (1992) in the area of Newfoundland, Canada conducted a study of twelfth-grade students (n = 30) to uncover misconceptions related to basic properties of atoms and molecules. The study used twelfth-grade students to continue investigations from studies done in the late seventies of students ages 12-13.

The authors selected subjects of varied ability and experience from 10 high schools through partially structured interviews exhibited 52 misconceptions. The authors then grouped the misconceptions into 11 categories for the purpose of analyzing possible differences by academic ability and experience in science classes.

The authors found no significant differences of misconceptions between ability and experience. This is important to note because it indicates an ability to apply similar assumptions on intuitive misconceptions as a starting point for curriculum development. Only two of the 52 misconceptions showed any significance of chi-squared values ($p < 0.05$, x^2 = 6.04, $df = 2$). Furthermore, qualitative findings illustrated that many misconceptions mirrored those seen historically in the development of the concepts tested. The intuitive misconceptions recorded from the subjects' interviews mirrored the historical development of conceptual thought.

Because this investigation was designed to continue research done previously on younger subjects, maturation was taken into account. A larger sample size could have increased the validity of the study as well as the use of a larger age range at the time of the study so as to not compare different generations.

The previous research indicates that it might be important to revisit concepts that contain common misconceptions. Otherwise, because individuals create conceptual frameworks for understanding it is possible to retard intellectual development of new concepts even if they are seemingly unrelated to common scientific organization of thought.

The section below provides an overview of literature that described the development of misconceptions throughout an individual's intellectual development as well as the development of specific misconceptions.

Developmental Stages of Conceptual Change

The two papers below investigated the effectiveness of specific strategies for the promotion of conceptual change from specific misconceptions. In addition to the findings that surrounded their initial questions, they also revealed some patterns of the nature of misconceptions as well as possible pedagogical practices that may promote undetected lingering of misconceptions.

Thompson and Logue (2006) in Australia investigated the persistence of misconceptions that students from ages six to fifteen (n = 6) commonly exhibited in reference to floating, precipitation, and classification of animals. The researchers utilized practical activities for the floating misconception, verbal responses for precipitation, and a questionnaire for classification of animals to measure prevalence of misconceptions in subjects.

Of the misconceptions selected, most of the students maintained at least a basic concept that followed widely accepted criteria, however the researchers found that further questioning for details left many of the subjects without an explanation or a misconception. The authors noted that the development of misconceptions can be built upon sequentially just as knowledge of a concept can be built upon, as was observed in their older subjects. Authors indicated the integration of new and concepts with previous concepts learned as a way to interfere with the development of new misconceptions. While doing so to ensure students understand the information at a higher level than with rote memorization. Thompson and Logue indicated that it is important to promote of conceptual change as the misconceptions observed in older subjects were more resistant to change.

The authors indicated that it is possible that at least one of the misconceptions diminished through maturation. However, Thompson and Logue revealed that in some cases the older subjects maintained more complex misconceptions as discussed previously. Thompson and Logue's speculated that these misconceptions increased in complexity just as accepted knowledge increased in complexity. The implications of these findings illustrates the possible consequences of misconceptions potential interference with comprehension of new information. Thompson and Logue's findings of increased resistance to conceptual change over time and increased complexity establishes the necessity to identify and address student misconceptions as early as possible in instruction.

The previous investigation indicated that rote understanding of concepts allowed students misconceptions to persist and additionally be used to form new conceptual frameworks, which can create new misconceptions. The investigation below attempted to look specifically at the development of misconceptions at various ages based on a common intuition used to understand a specific event. Other common misconceptions have been linked to intuition used to understand various events, but are not indicated in this study.

Levin, Siegler and Druvan (1990) carried out two experiments to determine if children and adults bear a single-object/single motion intuition that is prone to misconception and if so if a treatment of kinesthetic experience was effective enough to broaden subjects conceptual framework to overcome misconceptions.

The subjects (n = 240) were children in third, sixth, and ninth grade in an urban upper middle class school district near Tel-Aviv and humanities undergraduates from Tel-Aviv University. Each age group was contained the same number of subjects (n = 60) and was equally distributed male (n = 30) and female (n = 30). All subjects were randomly assigned one of three groups with related questions. Subjects were asked a question about motion, asked to explain their answer then produced a final judgment and sorted cards in their answer.

The researchers found that even undergraduates and ninth-graders who were assumed to have more experience in their personal and educational lives with speed exhibited the single object / single motion intuition ($p < 0.01$). However, the second experiment that utilized kinesthetic experience for sixth-graders ($n = 73$) that directly confronted the misconceptions uncovered in the first set of results produced a success rate of 50 percent of students that overcame their misconception. The authors did not explicitly reveal in detail the strategy involved the creation of the kinesthetic experiences or on what grounds the experiences deemed to directly confron misconceptions. Without these details it is difficult to determine the affective differences between treatments or ablity to duplicate the treatments with other groups of subjects. However, this study determined that a misconception not directly confronted can remain as part of a student's cognitive framework throughout educational development. Therefore the findings of Levin et. al. indicate that if left un challenged a misconception that a student develops early in education can persist and reduce the individuals potential for conceptual understanding of other concepts.This confirms the previous studies findings from Thompson and Logue (2006) in Australia of misconception persistence.

Although the researchers reported success with the treatment, it was only slightly significant ($p < 0.01$) and conceptual change represented in only half the subjects the results should be applicable as part of instruction design. It is important to note other strategies obviously will be necessary to promote conceptual change for all groups of students. As analysis was based on open ended questioning design errors in coding for analysis may have occurred as interpretation by researchers may have influenced results.

The previous study exhibited the length of time by which misconceptions can remain prevalent even with continued education without the misconception being directly addressed. This in addition to the information that even through developmental stages misconceptions can stay in place leads to the next subsection of investigations that examined the nature of various misconceptions over time through intellectual development as well as possible consequences of allowing misconceptions to prevail.

Maturation of Misconceptions

The following papers attempted to reveal the prevalence of misconceptions over time when not directly addressed even though subjects continued their intellectual development through formal education. To illustrate these findings researchers observed various age groups with use of common intuitive misconceptions.

The research below aimed to investigate possible patterns in development and degeneration of common misconceptions from fifth grade to pre service teachers.

Fischbein and Schnarch (1997) in Israel explored the development of intuitive misconceptions in relation to age of the subject. A questionnaire of seven basic problems that related to probability was administered to twenty students in grades 5, 7, 9, 11 (n=20) and pre service math teachers (n=18).

They found that some of the misconceptions increase with age, those the authors generally expressed as general principles (intuitive misconceptions) that were not generally confronted in everyday life, and some decreased with age, those that were confronted with problems that could not be satisfied by the misconception. This may lead to the development of effective strategies not generally utilized in formal education.

Fischbein and Schnarch (1997) performed the questionnaire during normal and unusual class times although they did not define what the definition of unusual meant or what the implications might be. In addition although the representation of various ages participated in the study it was not clear how the subjects were selected.

As with the previous study the investigation below intended to uncover possible patterns in the prevalence and possible degeneration of common misconceptions . In addition to the findings of persistence of misconceptions over time without confrontation of misconceptions Fischbein and Schnarch (1997) additionally revealed some misconceptions expressed reduction over time. This may reveal the possibility of ways to promote conceptual change in ways other than formal education as discussed in chapter 2 from research of Lave (1973).

Abraham, Wiliamson, and Westbrook (1996) performed a cross-age study (n=300) of misconceptions of five chemistry concepts. The study aimed to determine how age and development of formal education may effect conceptual change of several common misconceptions.

They measured for experience as well as reasoning ability as possible reasons for higher conceptual status of the five concepts. One hundred junior high, high school, and undergraduate students were evaluated on the conceptual status of chemical change, dissolution of a solid in water, conservation of atoms, periodicity, and phase change.

Reasoning ability was significant for conservation of atoms and periodicity, and grade level or maturation was significant for chemical change dissolution of a solid, conservation of atoms and precocity, even with few of the undergraduates understanding chemical change, phase change, or precocity. This study was significant to understanding the promotion of conceptual change by the ability to determine what kind of strategies could be effective for specific concepts.

All of the subjects belonged to the same district and feeder districts. The junior high fed into high school and many of the students at the community college fed from the high school. Although this research design allows for a clear comparison of age in relation to conceptual change it limits the generalbility of any results that expressed experience as the lead reason for confrontation of misconceptions. These subjects being of the same region and school system are likely to have similar experiences that may vary culturally and geographically and may differ across various cultures and geographic locations.

The previous investigations tested the prevalence and progression of specific common misconceptions at various ages of students. Both found variance between misconceptions. Some common misconceptions decreased with age and intellectual development and some increased. It is presumed by the research that maturation of intellectual development as well as the concepts susceptibility to confrontation that attributed to the previously noted decreases. The investigation below tested the prevalence of common misconceptions held by pre service teachers within their subject area. The purpose was to explore the possibility of common misconceptions even of students who focused on the content.

Gabel and Samuel (1987) conducted a Nature of Matter Inventory to determine misconceptions of pre service elementary school teachers on knowledge of matter they would need to teach the subjects common in elementary science textbooks (n = 90). Sixty percent of the subjects had received previous instruction in chemistry (n = 54).

The Nature of Matter Inventory included fourteen problems where subjects were required to draw a picture when a physical change occurred. The inventory was designed to measure the subjects' conceptions of what the authors considered basic principles of chemistry. These included; mixtures, substances, solutions, solids, liquids, gases, and chemical and physical changes. The chemistry professors that graded the tests exhibited agreement 95% of the time in practice for the investigation.

Of the subjects consisting of pre service teachers sixty percent had received prior education in high school and college chemistry, however the results concluded that the instruction they had previously obtained at the time of the study did not assist students' concepts of basic chemistry in satisfactory ways for most of the standards. Therefore as previously concluded with afore mentioned investigations although the students maintained knowledge from rote memorization they did not maintain accurate knowledge of the concepts. This finding adds support to the need for higher order thinking in the promotion of conceptual change for some misconceptions.

This study did not explicitly related the table of statistics from quantitative analysis with the findings discussed or report the p values for their supposed significant findings.

The previous investigation performed in the United States and the investigation below performed in the United Arab Emirates posed similar questions both with pre service teachers. Both attempted to uncover possible patterns in misconceptions observed within the pre service teachers disciplines and reasons they may exist.

Haidar (1997) in the United Arab Emirates investigated the conceptual framework and possible misconceptions of pre service chemistry teachers (n=173) in their junior and senior years of school on central concepts to chemistry.

An open-ended questionnaire was prepared on based on results from preliminary research to determine what common misconceptions occurred the population (n=9). The questionnaire attempted to uncover common misconceptions that included author acclaimed basic concepts such as the mole, atomic mass, balancing chemical equations and concepts of conservation of atoms and mass.

Of all the basic chemistry concepts analyzed pre service teachers only exhibited full understanding in balancing chemical equations. In addition among knowledge exhibited by the pre service teachers none show a correlation of reason behind the acquisition of said knowledge. The authors reported that subjects' knowledge manifested of the other concepts was based on memorization and not conceptual knowledge.

Haidar (1997) reported quantitative findings only as percentages and without statistical analysis although significance was claimed.

As with previous sections researchers noted connections between learning base on only rote memorization and high levels of common misconceptions in their subject groups. The subsection below included literature that investigated possible connections between specific preconceptions or notions about a subject and intellectual resistance to conceptual change.

Preconceptions That Inhibit Conceptual Change

In addition to strategies to address misconceptions directly the following papers investigated the possibility of connection between preconceptions that may not seem to be directly connected to the understanding of specific concepts. These include the practice of rote memorization and cultural or media based ideas formed into intellectual framework by which other concepts are developed and understood. In addition to learning practices and individual framework several pedagogical practices are identified by various researchers in the promotion and growth of particular misconceptions and misconceptions in general.

Nakheleh (1992) presented a cognitive model for learning chemistry and explored students' chemical misconceptions in grade nine (n=17), ten (n=300), eleven (n=11), and twelve (n=17). Subjects were interviewed, asked to fill out questionnaires on similar conceptual matter for their perspective grade levels. The interviews and questionnaires were not similar, but were based on the content.

Nakheleh (1992) concluded that there are many misconceptions that persist across many cultures, that many basic chemistry concepts are learned by rote memorizations and therefore are not able to be applied in novel situations, In addition she noted that many misconceptions are formed when students use common meanings for words in attempts to understand instruction, and that misconceptions are also harbored when students learn several definitions for the same phenomena. These findings could assist in the guidance of curricular design with the expressed failure of rote memorization as the mode for concept attainment and explicit comparisons in explanation of concepts.

Although the descriptions of the findings detailed implications the actual demographics and subject selection process was not disclosed. This lack of design information may affect the generability of Nakheleh's (1992) specific findings of misconceptions persistence across cultures although similar findings have been noted in previously described investigations.

Hennessey (1999) of St. Ann School in Stoughton Wisconsin conducted a study to examine the nature of metacognition, process of increased metacognitive capabilities, and the role of pedagogical practices and metacognition. Students in grades one through six were examined in a naturalistic study, all six cohorts were included, and all received science education of similar pedagogical framework by the same instructor.

Data was collected through interviews and recordings and written work produced by the students. The author reported that metacognition was successfully demonstrated by all ages even the first graders, that metacognitive ability is multifaceted, changes in metacognitive sophistication improves with active engagement and metacognitive ability and conceptual understanding may be closely linked to student's epistemological stance on science.

Data analysis was reported as positive in favor of metacognitive practices however despite detailed descriptive analysis actual statistics were not reported. In addition, although a research design model accepted by the educational community the Hennessey (1999) used their own students and teaching for the study, which could be subject to considerable bias. The subjects compromised of a stable population belonged to a small upper middle class Midwest community parochial school may not be a comparable population to many schools with larger class sizes and of various cultural and environmental compositions,

In a quantitative and qualitative study, Hadi-Tabassum (1999) evaluated a two-way immersion model with both Spanish and English speaking children in an eighth grade solar energy science classroom to increase retention rate in Hispanic students and motivation in students overall. They intended to evaluate implications of implementation for reform policy and practice. Researchers administered surveys to students (n=23), to determine their attitude toward science and its relevance to their future with a Likert scale measurement.

Students studied were academically at risk students as indicated by low test scores, socio-economic status, and low English proficiency. The application of the two-way immersion language model was intended to increase Hispanic student involvement and thus retention and motivation. In addition a cooperative group infrastructure was utilized to decrease status conflicts in academic and social realms.

Hadi-Tabassum (1999) concluded that there was an increase in positive attitude range and thus attitudes were more spread out than before the treatment. As discussed in chapter one rational and chapter two negative epistemologies of science may inhibit conceptual change. Therefore the two-eay immersion language model for some Hispanic English language learners increased positive epistemology of science, which could lead to increased conceptual change.

The study failed to report what students scores changed and thus the claim of the treatment being successful for Hispanic students and students as a whole would need more investigation. In addition student maturation or aspects of teacher personality or demeanor could be a factor in the positive attitude change toward science as the treatment was a full year. The reliability of the study was increased by use of a case study of students of similar demographics in other schools and regions and English Language Learners of other ethnicities.

McKeachie, Lin, and Strayer (2002) conducted a study of the effects that creationist belief had on students (n=60) conceptual framework around learning biology in a United States Midwest community college.

Of the 60 students that completed the pretest questionnaire only 28 completed the posttest questionnaire, with nineteen of the students dropped from the course. And thirteen failed to take the questionnaire with a disproportionate amount being students who self reported not believing in evolution.

Students who rated themselves somewhere between creationist and accepting evolution continuum tended towards a conceptual change in accepting evolution and did better academically in the course. Those students who self reported as not accepting evolution also rated low on learning strategy scales, they relied more heavily on memorization than students in other areas of the continuum.

Although not reported by McKeachie, Lin, and Strayer (2002) it is possible that their results could be related to students with creationist beliefs negative epistemologies of science not addressed by the treatment instruction. If instruction maintained an insensitive slant to students cultural beliefs as discussed in previous chapters it may be the treatment and not the belief that could be indicated in prevention of conceptual change.

Smith, Maclin, Houghton, and Hennesey (2000) reported on the epistemological development of two classes of sixth-graders in the Midwest of the United States of the St. Ann School and neighboring public school.

One taught from a constructivist perspective and one from a more traditional perspective. All subjects were interviewed with the Nature of Science Interview to gauge misconceptions and the development of students' epistemologies in regards to science. The authors' findings included that students taught from a constructivist perspective developed a knowledge problematic epistemology in which the students understand the tentative, framework-relative nature of knowledge, which follows principle of performance and participation in science. Students from a traditionally taught class developed a knowledge unproblematic epistemology from instruction that heavily relied on rote memorization for conceptual attainment, in which knowledge is seen as true and certain which authors indicated lead to significantly more misconceptions.

These findings support concerns from chapter one rationale of the development of negative epistemologies of science stemmed from a concept of science itself as rote memorization. In addition findings of rote memorization as the only avenue for conceptual attainment Smith, Maclin, Houghton, and Hennesey (2000) reported in alignment with other studies as increased inhibition of conceptual change.

The subjects composed of a stable population belonged to a small upper middle class Midwest community parochial school may not be a comparable population to many schools with larger class sizes and of various cultural and environmental compositions,

Robbins and Roy (2007) employed an instructional treatment of evolution that was inquiry-based to gauge it's effectiveness at correcting non-science student's (n=141) preconceptions as identified previously to the treatment.

The investigation began by identification of preconceptions then challenges were presented to those misconceptions described as instruction focused on evidence and logic inquiry models. Summative assessment was performed in understanding of evolutionary theory, acquisition of knowledge about evidence for evolution, and participation and acceptance of evolution.

Before the instructional treatment 59 percent of students reported they agreed 'unconditionally' with the theory of evolution. Based on formative assessments, end of course examination, and open-ended questionnaire the authors determined 89 percent mastered all aspects. In addition, students participated in an open-ended survey explicitly stated to not affect their grade and 92 percent reported acceptance of evolution.

Robbins and Roy (2007) expressed and increase in conceptual change from misconceptions with use of evidence and logic inquiry instruction models. These findings support the use of instruction models that employ higher order thinking. In inquiry models of instruction rote memorization is sparingly if ever employed.

The assessments were not included in the paper and thus not available for outside evaluation. Robbins and Roy (2007) only performed quantitative analysis in reference to percentages as they either did not calculate or did not report statistical analysis although they claimed significant results of their treatment of evidence and logic inquiry instruction models for evolution. In addition the possibility of negative epistemologies was not addressed.

De Vos and Verdonk (1987) conducted a study of 14- and 15-year-old chemistry students to determine if the instructional use of analogy aids in concept formation. The study conducted in the Netherlands by observation and recorded answers to open ended questions designed to unearth student misconceptions. Prior to the questionnaire the authors utilize a treatment in small and whole group discussion on behavior of molecules with a use of analogy driven teacher derived terms that were perceived by the authors to be learner friendly.

The intent of the authors was to gauge the effectiveness of the analogy driven teacher created terms on conceptual change in the students. The authors utilized the student misconceptions to drive instruction. They attempted this with a format of instruction guided by evolving analogies and altered word usage to bypass students' misconceptions to promote conceptual change. The authors defined their altered word usage as imagined vocabulary. This method was utilized in hopes to avoid possible misuse of connotations of terms such as those used in social and scientific terms that contain multiple meanings.

De Vos and Verdonk reported "When the analogy was effective enough that the students upon evaluation of the analogy did not have intellectual issues with the analogy was deemed able assist students in synthesizing information that was necessary to overcome their misconceptions of reactions and molecules." Most students at the end of the treatment could identify, but not apply the concept at the end of the treatment. Thus in support of previously reported research strategies must include students use of higher order thinking for adequate conceptual change. This particular treatment allowed students to understand the information, but not always at the cognitive level of application.

A questionable aspect to this study is that the sample set was described as large by the authors, however the actual number and demographic information of the subjects were not described. Without the actual sample set and demographic information it is difficult to extrapolate the findings across demographics.

The previous subsection reinforced some of the previous findings of the described in the nature of misconceptions, as described in chapter 2 the history of research on conceptual formation and change, and in chapter 1 in the rational for the importance of understanding misconceptions as an educator. The following section specifically evaluates research aimed to determine strategies proven effective at the promotion of conceptual change.

Evaluation of Strategies to Promote Conceptual Change

The following section includes a sample of research aimed to investigate various pedagogical practices and strategies to promote conceptual change. The previous topic section aimed to provide a generalized swath of research to assist educators in understanding misconceptions, preconceptions, and conceptual change. The sections below are aimed to give specific ideas of what had and had not been found to be effective at the promotion of conceptual change.

The sections are split into two subsections, *Effective Strategies Researched in the United States* and *Effective Strategies Researched Outside the United States*. The subsections are divided by inside or outside the United States because convincing arguments can be made to include and reject the use of research from outside the United States for classrooms inside the United States. Not only was the research included because of relevance to the inclusion of various cultural attitudes towards effective education but also because many of the findings answered some of the questions left behind on whether or not the findings from the United States which used mostly subjects in the Midwestern portion of the United States in middle class or upper class neighborhoods. As will be noted in the subsection *Effective Strategies researched outside the United States* cultural variances such as motivation and educational environment may skew the ability to compare populations and the effectiveness of strategies.

Effective Strategies Research in the United States

The papers below describe research aimed to investigate specific strategies for the promotion of addressing common misconceptions in science and science related topics. Much of the educational research on misconceptions and conceptual change in the United States was performed with a small demographic of subjects in the Midwest middle to high socioeconomic status.

Several main pieces used the same parochial school for observations and research. The second subsection *Effective strategies researched outside the United States* aimed to provide educators with applicability of various strategies and practices.

Hewson and Beeth (1993) reported general guidelines for conceptual change observed from a fifth grade (n=13) parochial school that focuses instructional design on conceptual change.

This study was conducted by the authors' observation of a fifth grade classroom that had received continuous instruction in science from the same instructor. The instructor is a science teacher and principle of the private school. How the study was conducted was not explicitly outlined as far as what was deemed effective and what was not and how they coded or recorded such instances.

The guidelines include: students' ideas as and integral part of the lesson, conceptual status of ideas should be discussed and negotiated in small and whole group, justification for ideas needs to be explicit, and metacognition should be explicit aspect of the classroom.

The investigative design does not account for the small class size, continuous exposure to concepts throughout their education, and possible cross-cultural effectiveness, as the subjects are of a specific demographic of privileged children.

A follow-up investigation of instruction that would support conceptual change as conducted by Beeth and Hewson (1997) specifically to attempt to address the effectiveness of metacognition for conceptual change.

Some unique aspects of instructional strategy are identified after extensive observation of the classroom environment and instruction strategies that the authors credit to the effectiveness of challenging students' misconceptions in science.

Some of the aspects are as follows: academic learning goals based on metacognition, small and whole group instruction, students maintain environmental security with same classmates and teachers for all of elementary school, mastery of concepts as goals, conceptual instructional framework. The aspects reported by Beeth and Hewson (1997) as effective for the promotion of conceptual change involve the use of higher order thinking including metacognition in addition to the findings from *Nature of Misconceptions, Preconceptions and Conceptual Change* of importance of ancillary effects on conceptual change such as classroom environment.

Neither the quantitative information of observation hours nor any form of coding system was revealed for this study. The investigative design does not account for possible cross-cultural effectiveness, because the subjects are of a specific demographic of privileged children.

Beeth and Huziak (2001) investigated 617 student inquiry articles in the "I Wonder" science journal for elementary school students to see what portion of the students were working from a science framework and what students were working from an engineering framework in the students' studies. In addition to the determination of whether a student publishing journal would encourage or motivate conceptual change

The journal is published annually and was scanned by authors for subjects' use of scientific or inquiry-style thought or engineering-style thought. Engineering-style thought is categorized by the focus of the subject on building something as opposed to understanding how something is affected or affects.

The authors concluded that as evident by the articles students were able to participate in a developmental science community that encouraged learning in science. Participation in the journals exhibited scientific inquiry as well as various cultural and mathematical concepts, which could have a positive effect on student epistemologies of science and promote conceptual change of science and various scientific and engineering concepts and topics.

However they did not allude to how many or what students used which kinds of thought. The study failed to report demographics of participating students therefore the applicability of observations to various demographics such as age, culture, and gender are uncertain.

Nehm and Reilly (2007) choose two groups of students in a second semester biology course, one in an active learning class and one in a traditional lecture style class to investigate knowledge and misconceptions after a semester in a college level biology course on natural selection at City University of New York.

Assessment of misconceptions was performed before and after the twelve week course by an open response paper and pencil instrument and in an oral script. The mean age of students was 21, females made up 61 percent of the group. Racial and ethnic demographics were as follows; Hispanic 32.5 percent, African American 30.12 percent, Asian 25.5 percent; American Indian 0.09 percent, and white (non Hispanic) 11.75 percent.

The active-learning class was characterized by fewer misconceptions post course, however both classes exhibited an unsatisfactory understanding of natural selection. In addition to these results seventy percent of the active learning class and eighty six percent of the traditionally taught class employed one or more misconceptions in their explanations of natural selection.

These findings confirm that active learning as applied in this study alone does not fully promote conceptual change since neither group exhibited a full understanding as the goal determined.

The descriptions of instruction could have been more effective for application of findings if more explicit descriptions were supplied in the study. The implication based on lack of design description and previous study reports maintains that strategies such as active learning may not consistently promote conceptual change without the insurance of higher order thinking.

Podolefsky (2008) investigated the effectiveness of a new model of analogy, Analogical Scaffolding, which was described to be specifically tailored toward the challenge of not being able to have students work directly with physics concepts and topics such as electromagnetic waves.

Analogical Scaffolding was developed in pre research to the study. Two studies (n>100) were conducted with Analogical Scaffolding as a tool in taught and available in the treatment physics classes highlighted in the study. The author reported students in the treatment classes had significantly higher achievement on post assessments however the actual statistics were not reported.

The purported results are that analogies as designed in Analogical Scaffolding assist conceptual change by the creation of a learning tool for abstract concepts.

The layout and specifics as to how to perform the treatment was not explicitly described in the study nor was details about the students. The report was that the scores were significant over two or three times more effective however the p values and other statistics were not revealed.

Mevarech (1983) investigated mathematical misconceptions of freshman (n = 56) and sophomore (n = 47) college students. In addition, an attempt to measure conceptual change an instructional treatment that utilized developmental mathematics master learning strategies (MLS) was performed based on the data received from the initial investigation. Mevarech lead subjects freshmen majoring in education in the second investigation ; Mevarech randomized subjects into a treatment (n = 75) and a control (n = 64) groups. Achievement in math contained no significant difference between the two groups.

Both treatment and control groups received the same class book and time in the classroom that included the same number of days in the classroom itself and the lab. The courses included instruction on frequency distribution, measures of central tendency, measures of dispersion, and correlation. The control group received a traditional lecture-discussion strategy (LDS). The treatment instruction of MLS included; grading based on mastery of unit, presentation, a formative test based on misconceptions from the previous investigation, corrective activities for students who did not reach the mastery level, effectiveness monitored of corrective activities, and a summative test.

Subjects that received the instructional treatment of MLS did significantly better on the summative test, seventy percent of the treatment subjects and forty percent of the control group achieved mastery ($r = 3.20$, $p < 0.01$). These scores exhibited increased achievement and a reduction in misconceptions for subjects that received formative assessment and corrective activities therefore it may be effective for the promotion of conceptual change as a class structure.

However, demographic information on subjects did not exist therefore it its uncertain if this treatment would be applicable to all populations of students. With this in mind, Mevarech's findings are consistant to other previously stated findings that state that effective strategies can be recognized by the identification and instruction that directly confronts student misconceptions.

Eaton, Anderson, and Smith (1984) conducted a qualitative and quantitative study to explore the effectiveness of an instructional strategy of science instruction that included design tools to uncover and address students misconceptions formatively and one that did not, in 14 fifth grade classes in the Midwest of the United States with a focus on two classrooms with similar demographics, classroom environment, hands on experience, and textbook.

Eaton et. al. observed instruction and audio recorded and pre and posttests were collected and analyzed. The authors administered an identical test pre and post instruction; it contained forty-three short answer and multiple-choice questions.

Of the two classrooms that the study focused the classroom that implemented the instructional design that highlighted a conceptual framework and formative tools contained a higher percentage of students that understood the concept presented, 22 verses 79 percent.

Eaton et al. (1984) sought to examine the relationship between students' misconceptions about light, the textbook, class instruction, and what they learned, as part of the elementary science project. They utilized 14 intact fifth grade classrooms with teachers of who included science regularly in their classrooms. Of the 14, two teachers with similar student demographics were focused on. Both teachers used and had experience with the same text being used in the study. Observers collected data through observation in the classroom and audio recorded lessons. Short answer and multiple-choice pre and post tests were administered for each unit based on the textbook.

Results revealed of the six sample students, all six exhibited common misconceptions about light and seeing. Concluding the unit, five out of six students maintained their misconceptions. Of the 113 students who participated, only 30 percent exhibited change in their misconceptions toward commonly accepted light and sight science. Most of the 113 students (78 percent) had difficulty understanding the connection between light and sight. The following year, the authors administered the treatment curriculum to the same two samples teachers focused on teachers identifying and addressing misconceptions. Of the teachers' later fifth-grade class, 79 percent demonstrated understanding of the light and sight concept. Both first and second year fifth-graders were shown to have similar on-task behavior and accessed teachers. Of the students who showed conceptual understanding before the treatment, the authors reported use of higher order thinking of Bloom's taxonomy such as evaluation and synthesis.

The authors failed to report details about the instruction and demographics other than they reported that they viewed them as similar. Further detail about the students as well as details about the data collection process. In addition only the results of the two teachers out of fourteen were described in depth and amount of class time was not accounted for as a control. However they did include quantitative and qualitative data on over a hundred students.

Nakhleh (1990) utilized three treatment groups of equal size they were split into use of chemical indicators, pH meter, and microcomputer interfaced to a pH probe (MBL) to inquire about the possible effects they may have on students concepts of acids, bases, and pH. Subjects were high school chemistry students; the number of subjects was not reported.

The author conducted pre and post treatment interviews that contained examples, non examples and demonstrations by students of concepts verbally and with pen and paper diagrams. Students were split into three treatment groups to perform titrations; one with a strong acid and a strong base, weak acid and a strong base, and a polyprotic acid and a strong base. Nakhleh developed concept maps from the interviews to determine conceptual change.

All three treatment groups exhibited conceptual change, with the MBL group to a significantly greater extent. They authors purported a reason for this outcome based on an unconfirmed attempted explanation of how the use of the computer could have worked with short term to long term memory function. All treatments involved a lab that provided visual representation for phenomena, which could possibly directly confront misconceptions held before the treatments.

Nakhleh (1990) did not report the statistical data to support the findings of significant results of conceptual change. The sample set of subjects was also unreported. Without this information it is difficult to assess the validity of the study.

A twelve year study of learning of science concepts was performed on first and second grade students (n=191 and n=48) in Ithaca, New York through their twelfth year by Novak and Musonda (1991), and trained graduate students. The treatment group (n=191) received science instruction for first and second grade and the control group (n=48) received no science instruction until later with the treatment group as was traditionally prescribed by the school district during secondary education.

The treatment group received 4 instructed plant lessons and 60 audio-tutorial lessons during first and second grade. The authors choose to have a much larger treatment group even though they acknowledged a loss in reliability of the treatment because the children in the study were of the same school and the treatment was very popular with teachers and students. The lessons were focused on what authors deemed fundamental concepts of science and the 'process' of concepts.

Concept maps developed by interviewers utilized open-ended questioning and were scored with a scoring algorithm expressed significantly more valid science concepts in students in the treatment group and fewer misconceptions in grades two, seven, ten, and twelve. However there was not a significant difference in either groups SAT or GPA scores. This was attributed to both the SAT and GPA being based on rote memorization of vocabulary and facts as opposed to science concepts. This study established the possibility that early science instruction that confronted misconceptions led to fewer misconceptions later in life even with similar instructions of more complex science phenomena. This finding is in alignment with other studies that reported the ability for misconceptions to build over time.

Novak and Musonda (1991) successfully completed a long term educational study with a control group, a feat rarely accomplish. However there are several possibilities for study error. Over 12 years of study involved patchy times of data collect due to lack of funding and use of various people for coding subject responses. In addition although the control group made a easy comparison of demographics as the subjects were from the same age and school there could have been a possibility of transfer of information between subjects although unlikely with consideration of the significant results for higher conceptual understanding in students who received the treatment.

The previous research discussed investigations aimed to uncover strategies as explicitly effective or ineffective at the promotion of conceptual change as observed in subjects inside the United States. Below in the section *Effective Strategies Outside the United States* are educational research performed throughout the world aimed at the promotion of conceptual change and discovery of ineffective strategies and reasons for their ineffectiveness.

Effective Strategies Outside the United States

The Following research was aimed at evaluation of strategies to promote conceptual change. Subjects range from Australia to Korea to Israel and the Netherlands. In addition to others research from cultures in Africa and South and Central America is not provided the subsection. This research provided possible connections and variations between cultures and the effectiveness at the promotion of conceptual change.

Ben-Zvi, Eylon, and Silberstein (1986) investigated the preconceptions of tenth graders in eleven chemistry classes throughout Israel ($n \geq 300$), followed by a program to prevent misconceptions and evaluation of the program. All of the students had received at minimum half a year of chemistry instruction prior to the investigation.

Ben-Zvi et al. investigated subjects' preconceptions with a multiple choice and short answer questionnaire; responses were analyzed into five main categories of preconceptions to be addressed with the treatment. The treatment consisted of an instructional model that followed the historic thought behind the concept. Instruction began historically where a majority of the students' preconceptions were common among the scientific community with a subsequent model, followed by the newer version of the concept of model in the historical context. The authors had a large control group (n=538). They hoped to investigate the relation between how they understood the atom and how they understood a compound.

The results of the evaluation of the new program reported 43.7% of the students that received the treatment acquired an acceptable understanding as compared to 18.4% of the control group. The authors found that students who had a more complete understanding of the atom also had a more complete understanding of the nature of the compound. These findings are in alignment of the sub section *Links between historical and developmental conceptual development* as the instruction modeled after historical development of the concept successfully promoted conceptual change. The conceptual change exhibited in part of the concept that lead to conceptual change for the larger concept aligns with the findings in the sub section *Development of conceptual change* and results that indicated that agreed upon understandings as well as misconceptions can create a mental framework by which additional knowledge is built upon and filtered through.

Further research could be performed to examine the use of a similar treatment for different demographics of students. It is not clear from this study if any early instruction in science would promote conceptual change later in life or if it can be attributed to this particular treatment.

Noh and Scharmann (1997) in Korea tested for effectiveness of a Molecular-Level Pictorial Presentation of Matter on Korean high school students' concepts of some fundamental chemistry concepts.

The students were broken up into two groups, treatment with pictorial representation (n = 49) and control group with regular instruction (n = 49). During the observations to insure reliability the control received a much higher level of the treatment than the treatment group. These findings support previous discussion of some mode of direct confrontation of possible misconceptions to promote conceptual change

Despite this the authors reported that analysis of covariance results expressed that the treatment helped students construct more accurate frameworks, however it did not express any changes for problem solving ability.

Major problems in the reliability of the study exist as Noh and Scharmann (1997) reported major problems in the instructional application of the treatment.

Observation of the treatment and control groups indicated the treatment was more commonly used with the control group than the treatment group.

Kwon, Lee, and Beeth (2000) in Korea attempted to discover the relation between the level of conceptual conflict otherwise defined as disequilibrium and conceptual change in the student.

Tenth graders (n = 30) were selected in pretest results as the focus of the research based on the shared misconceptions out of 450 students. Two classroom strategies were analyzed, logical arguments and demonstration. Logical arguments were categorized by an instructional treatment of presentation of a description of the information. Demonstration was categorized by a physical model presentation of how the topic being presented.

The demonstration effectively obtained conceptual change more often than logical argument and students with higher conflict levels showed more positive conceptual change. Since demonstration indicated by Kwon, Lee, and Beeth (2000) to maintain higher levels of disequilibrium their findings align with links discussed previously in studies from the other geographic regions of the promotion of conceptual change as driven by disequilibrium.

The study could be more effective if demographics of the students was described in more detail and the treatment was tested on populations of various demographics to decipher if this treatment is effective in different educational systems.

Sarikaya (2007) in Turkey applied an activity Modeling of the Atomic Structure (MAS) in order to attempt to help challenge pre-service teachers' misconceptions about basic atomic structure in the context of electrification by friction.

Sarikaya (2007) first identified misconceptions pre service teachers had about the topic, then analyzed for differences among differences in disciplines (science and humanities), and finally applied the treatment and analyzed for effectiveness.

Pre service teachers across disciplines held similar misconceptions about atomic structure and friction. Only science disciplines as a whole group and humanities as a whole group showed significant differences in number of misconceptions, subjects in science disciplines had fewer misconceptions ($p < 0.05$, $F = 1.29$, $p = 0.27$, μ^2 = 0.03). In addition the treatment that utilized the use of models showed significant change in challenging misconceptions of pre service teachers. Since demonstration indicated by Sarikaya (2007) to maintain higher levels of disequilibrium their findings align with links discussed previously in studies, such as Kwon, Lee, and Beeth (2000), from the other geographic regions of the promotion of conceptual change as driven by disequilibrium.

In Perth Australia, Tsui and Treagust (2007) of the Curtin University of Technology assessed the effectiveness on student conceptual change in genetics after an instructional treatment of the computer program BioLogica with a cross-case analysis with conceptual status analysis categories.

BioLogica is one of many computer based programs that act as a supplement to science instruction that provides students with multiple representations of concepts. The students (n = 89), seventy two of which were females were of different socio-economic status and were nearly all Australian born, received varied amounts of instruction with BioLogica.

As a result of the study the authors concluded that subjects did show significant effectiveness in conceptual change with the multiple representation software in genetics with some variation between individuals even with differences in usage between the three classrooms. These results correlated with previously discussed findings of the effectiveness of treatments shown to directly confront misconceptions as well as the need for various strategies to promote positive conceptual change for all students.

As all three groups were made of college preparatory schools motivation and classroom environmental factors should be considered as a non controlled variable in this study.

The previous subsection aimed to establish commonalities as well as variance between cultures to determine what strategies were found effective, how they were or were not effective, and in what conditions.

Chapter 3 as a whole reviewed a sample of literature that attempted to establish the nature of preconceptions, misconceptions, and conceptual change as well as report what was effective, what was ineffective, and under what conditions may sway strategies to contradict the outcome from the studies themselves.

Chapter 4 will summarize the findings and implications from chapter 3 while it responded to possibilities left undetermined by the literature in chapter 3 and chapter 2 as it attempted to answer the main question as described in chapter 1 and respond to the concerns presented in chapter 1 and throughout the description of literature theoretical and research based in chapter 2 and chapter 3 respectively.

Chapter Four: Conclusion

Introduction

Each individual has a conceptual framework from which they operate. Common ideas are formed about concepts and topics in science and math that work sometimes, but without the consistency that is necessary for deeper thought and knowledge. Thus misconceptions are developed which can lead to an entire conceptual framework based on misconceptions. This review of literature was to explore effective strategies for challenging students' math and science misconceptions.

Piagetian and neo-Piagetian developmental theory stated that young children were not developmentally capable to use or understand higher order thought as specified in Blooms' taxonomy. This was based on observations and interviews of children in school systems that did not perform curricula or assess for higher order thought such as abstract thought and synthesization, both of which are required to practice science methodology. Thus science and other curricula was produced to follow the prescribed developmentally sensitive aspects of concrete and fact based thought until later in life, commonly not until college and graduate school, which continued to produce citizens that were not practiced in higher order skills in relation to math, sciences, history and other curricula topics.

This chapter will summarize findings of effective strategies for addressing misconceptions, implications for the classroom based on the researchers' findings, and suggestions for future research that would supplement the already existing knowledge.

Summary of Findings

A overarched theme in the research is that many of the instructional treatments that have been shown to be effective at conceptual change for subjects do not change their academic status on examinations such as the SAT, as it is a fact based assessment, despite the intellectual advantages. The following is a summary of findings from chapter three.

Brown (1992) concluded that for both examples and analogies to be effective they must be understandable and believable to the subject by explicit development of an analogous example and models that the subjects can visualize to mechanistic explanations, analogies, to phenomena. As was predicted by the author, presentation of phenomena with supporting examples did not exhibit significant conceptual change. The investigation contained detailed examples of the common misconceptions and attempted conceptual change by treatments. The findings of believable examples linked to higher success rates ($p < 0.0001$) did not surprise Brown (1992), however more successful examples did not prove alone to be as successful at the promotion of conceptual change in all circumstances as when educators explicitly developed relationships between the example or analogy and the actual phenomena.

Information gathered from the qualitative interviews supported the quantitative findings. The interviews revealed that subjects reverted to intuitive misconceptions when the relationships between analogy or example and the actual phenomena was not explicitly developed or explained. This is relevant to the effectiveness of strategies for creation of conceptual change by the established need for believable and explicit relationships between examples or analogies and actual phenomena. This knowledge may help educators be more effective especially for students of cultures varied from their own and thereby address some of the concerns of negative epistemologies discussed in chapter one and two.

Barlia and Beeth (1999) conducted a study of motivational factors for conceptual change. The authors reported that individual differences were present for every student, but that task value and control beliefs are most important for most students in addition to factors not in the analysis such as teacher personality. Barlia and Beeth (1999) noted additionally that these findings imply the importance of educators' expression of enthusiasm for the subject and focus on more than rote memorization of facts to increase value of task importance to students.

Brown (1992), Barlia and Beeth (1999) found that such factors as teacher enthusiasm had impacts on many students abilities to achieve the conceptual change desired by the instructor, in addition both found that instruction must focus on more than rote memorization and statement of examples to promote conceptual change. It was suggested that explicit relationships between the example or analogy and the actual phenomena must be provided to promote conceptual change.

Research Linking Historical and Developmental Conceptual Change

Griffiths and Preston (1992) in the area of Newfoundland, Canada conducted a study of twelfth-grade students ($n = 30$) to uncover misconceptions related to basic properties of atoms and molecules. There were no significant findings in differences of misconceptions between ability and experience. This is important to note because it indicates an ability to apply similar assumptions on intuitive misconceptions as a starting point for curriculum development. Only two of the 52 misconceptions showed any significance of chi-squared values ($p < 0.05$, x^2 = 6.04, $df = 2$). Furthermore, qualitative findings illustrated that many misconceptions mirrored those seen historically in the development of the concepts tested. The intuitive misconceptions recorded from the subjects' interviews mirrored the historical development of conceptual thought.

Developmental Stages of Conceptual Change

Thompson and Logue (2006) in Australia investigated the persistence of misconceptions that students from ages six to fifteen ($n=6$) commonly exhibited in reference to floating, precipitation, and classification of animals. Of the misconceptions selected, most of the students maintained at least a basic concept that followed widely accepted criteria; however the researchers found that further questioning for details left many of the subjects without an explanation or a misconception. The authors noted that the development of misconceptions can be built upon sequentially just as knowledge of a concept can be built upon, as was observed in their older subjects. Authors indicated the integration of new and concepts with previous concepts learned as a way to assist to prevent the development of new misconceptions. While doing so to ensure students understand the information at a higher level than with rote memorization. Thompson and Logue (2006) indicated the importance of the promotion of conceptual change as the misconceptions observed in older subjects were more resistant to change.

Levin, Siegler and Druvan (1990) found that even undergraduates and ninth-graders who were assumed to have more experience in their personal and educational lives with speed exhibited the single object / single motion intuition ($p < 0.01$). However, the second experiment that utilized kinesthetic experience for sixth-graders ($n = 73$) that directly confronted the misconceptions uncovered in the first set of results produced a success rate of 50 percent of students that overcame their misconception. The authors did not explicitly reveal in detail the strategy involved the creation of the kinesthetic experiences or on what grounds the experiences deemed to directly confront misconceptions. Without these details it is difficult to determine the affective differences between treatments or ablity to duplicate the treatments with other groups of subjects. However, this study determined that a misconception not directly confronted can remain as part of a students cognitive framework throughout educational development. Therefore the findings of Levin et. al. indicate that if left un challenged a misconception that a student develops early in education can persist and reduce the individuals potential for conceptual understanding of other concepts. This confirms the previous studies findings from Thompson and Logue (2006) in Australia of misconception persistence.

Griffiths and Preston (1992), Thompson and Logue (2006), and Levin, Siegler and Druvan (1990) revealed that for many or all of the misconceptions they investigated neither ability nor experience alone promoted conceptual change. In addition it was revealed some of the misconceptions were used as a framework just as the brain uses other concepts as conceptual frameworks.

Maturation of Misconceptions

The following papers attempted to reveal the prevalence of misconceptions over time when not directly addressed even though subjects continued their intellectual development through formal education. To illustrate these findings researchers observed various age groups with use of common intuitive misconceptions.

The research below aimed to investigate possible patterns in development and degeneration of common misconceptions from fifth grade to pre service teachers.

Fischbein and Schnarch (1997) in Israel explored the development of intuitive misconceptions in relation to age of the subject. They found that some of the misconceptions increase with age, those the authors generally expressed as general principles (intuitive misconceptions) that were not generally confronted in everyday life, and some decreased with age, those that were confronted with problems that could not be satisfied by the misconception. This may lead to the development of effective strategies not generally utilized in formal education.

Abraham, Wiliamson, and Westbrook (1996) performed a cross-age study (n=300) of misconceptions of five chemistry concepts. Reasoning ability was significant for conservation of atoms and periodicity, and grade level or maturation was significant for chemical change dissolution of a solid, conservation of atoms and precocity, even with few of the undergraduates understanding chemical change, phase change, or precocity. This study was significant to understanding the promotion of conceptual change by the ability to determine what kind of strategies could be effective for specific concepts.

Gabel and Samuel (1987) conducted a Nature of Matter Inventory to determine misconceptions of pre service elementary school teachers on knowledge of matter they would need to teach the subjects common in elementary science textbooks (n=90)Of the subjects consisting of pre service teachers sixty percent had received prior education in high school and college chemistry, however the results concluded that the instruction they had previously obtained at the time of the study did not assist students' concepts of basic chemistry in satisfactory ways for most of the standards. Therefore as previously concluded with afore mentioned investigations although the students maintained knowledge from rote memorization they did not maintain accurate knowledge of the concepts. This finding adds support to the need for higher order thinking in instruction.

Haidar (1997) in the United Arab Emirates investigated the conceptual framework and possible misconceptions of pre service chemistry teachers (n=173) in their junior and senior years of school on central concepts to chemistry. Of all the basic chemistry concepts analyzed pre service teachers only exhibited full understanding in balancing chemical equations. In addition among knowledge exhibited by the pre service teachers none show a correlation of reason behind the acquisition of said knowledge. The authors reported that subjects' knowledge manifested of the other concepts was based on memorization and not conceptual knowledge.

Nakheleh (1992) presented a cognitive model for learning chemistry and explored students' chemical misconceptions in grade nine (n=17), ten (n=300), eleven (n=11), and twelve (n=17). Nakheleh (1992) concluded that there are many misconceptions that persist across many cultures, that many basic chemistry concepts are learned by rote memorizations and therefore are not able to be applied in novel situations, In addition she noted that many misconceptions are formed when students use common meanings for words in attempts to understand instruction, and that misconceptions are also harbored when students learn several definitions for the same phenomena. These findings could assist in the guidance of curricular design with the expressed failure of rote memorization as the mode for concept attainment and explicit comparisons in explanation of concepts.

Hennessey (1999) of St. Ann School in Stoughton Wisconsin conducted a study to examine the nature of metacognition, process of increased metacognitive capabilities, and the role of pedagogical practices and metacognition. Data analysis was reported as positive in favor of metacognitive practices however despite detailed descriptive analysis actual statistics were not reported.

In a quantitative and qualitative study, Hadi-Tabassum (1999) evaluated a two-way immersion model with both Spanish and English speaking children in an eighth grade solar energy science classroom to increase retention rate in Hispanic students and motivation in students overall. Hadi-Tabassum (1999) concluded that there was an increase in positive attitude range and thus attitudes were more spread out than before the treatment. As discussed in chapter one rational and chapter two negative epistemologies of science may inhibit conceptual change. Therefore the two-way immersion language model for some Hispanic English language learners increased positive epistemology of science, which could lead to increased conceptual change.

McKeachie, Lin, and Strayer (2002) conducted a study of the effects that creationist belief had on students (n=60) conceptual framework around learning biology in a United States Midwest community college. Students who rated themselves somewhere between creationist and accepting evolution continuum tended towards a conceptual change in accepting evolution and did better academically in the course. Those students who self reported as not accepting evolution also rated low on learning strategy scales, they relied more heavily on memorization than students in other areas of the continuum.

Smith, Maclin, Houghton, and Hennesey (2000) reported on the epistemological development of two classes of sixth-graders in the Midwest of the United States of the St. Ann School and neighboring public school. These findings support concerns from chapter one rationale of the development of negative epistemologies of science stemmed from a concept of science itself as rote memorization. In addition findings of rote memorization as the only avenue for conceptual attainment Smith, Maclin, Houghton, and Hennesey (2000) reported in alignment with other studies as increased inhibition of conceptual change.

Robbins and Roy (2007) employed an instructional treatment of evolution that was inquiry-based to gauge it's effectiveness at correcting non-science majors misconceptions. Robbins and Roy (2007) expressed an increase in conceptual change from misconceptions with use of evidence and logic inquiry instruction models. These findings support the use of instruction models that employ higher order thinking. In inquiry models of instruction rote memorization is sparingly if ever employed.

De Vos and Verdonk (1987) conducted a study of 14- and 15-year-old chemistry students to determine if the instructional use of analogy aids in concept formation. The study conducted in the Netherlands by observation and recorded answers to open ended questions designed to unearth student misconceptions

> "When the analogy was effective enough that the students upon evaluation of the analogy did not have intellectual issues with the analogy was deemed able assist students in synthesizing information that was necessary to overcome their misconceptions of reactions and molecules."

Most students at the end of the treatment could identify, but not apply the concept at the end of the treatment. Thus in support of previously reported research students must employ higher order thinking for adequate conceptual change. This particular treatment allowed students to understand the information even if not at a level of application.

Fischbein and Schnarch (1997), Abraham, Wiliamson, and Westbrook (1996), Gabel and Samuel (1987), Haidar (1997), Nakheleh (1992), Hennessey (1999), Hadi-Tabassum (1999), McKeachie, Lin, and Strayer (2002), Smith, Maclin, Houghton, and Hennesey (2000), Robbins and Roy (2007), and De Vos and Verdonk (1987) stated that intuitive misconceptions can persist across many cultures and that some of the misconceptions increase with age. Those the authors generally expressed as general principles or intuitive misconceptions, that were not generally confronted in everyday life, and some decreased with age, those that were confronted with problems that could not be satisfied by the misconception. Concepts learned by rote memorization could not be applied in novel situations nor did the subjects maintain accurate knowledge of the concepts. The authors noted failure of rote memorization as the mode for concept attainment. One of the reasons for this revealed by several subjects indicated the use of rote memorization as the core means for instruction as a means for the development of negative epistemologies. Some of the following strategies identified as successful in promoting conceptual change included: metacognitive practices, increased positive epistemology of science, and instruction models that employ higher order thinking such as inquiry based science instruction.

Evaluation of strategies to promote conceptual change

Effective Strategies Research in the United States

Hewson and Beeth (1993) reported general guidelines for conceptual change observed from a fifth grade (n=13) parochial school that focuses instructional design on conceptual change. The guidelines include: students' ideas as and integral part of the lesson, conceptual status of ideas should be discussed and negotiated in small and whole group, justification for ideas needs to be explicit, and metacognition should be explicit aspect of the classroom. All aspects determined by Hewson and Beeth (1993) as effective for the promotion of conceptual change involve the use of higher order thinking including metacognition.

A follow-up investigation of instruction that would support conceptual change as conducted by Beeth and Hewson (1997) specifically to attempt to address the effectiveness of metacognition for conceptual change. Some of the aspects are as follows: academic learning goals based on metacognition, small and whole group instruction, students maintain environmental security with same classmates and teachers for all of elementary school, mastery of concepts as goals, conceptual instructional framework. The aspects reported by Beeth and Hewson (1997) as effective for the promotion of conceptual change involve the use of higher order thinking including metacognition in addition to the findings from *Nature of Misconceptions, Preconceptions and Conceptual Change* of importance of ancillary effects on conceptual change such as classroom environment.

Beeth and Huziak (2001) investigated 617 student inquiry articles in the "I Wonder" science journal for elementary school students to see what portion of the students were working from a science framework and what students were working from an engineering framework in the students' studies. In addition to the determination of whether a student publishing journal would encourage or motivate conceptual change. The authors concluded that as evident by the articles students were able to participate in a developmental science community that encouraged learning in science. Participation in the journals exhibited scientific inquiry as well as various cultural and mathematical concepts, which could have a positive effect on student epistemologies of science and promote conceptual change of science and various scientific and engineering concepts and topics.

Nehm and Reilly (2007) choose two groups of students in a second semester biology course, one in an active learning class and one in a traditional lecture style class to investigate knowledge and misconceptions after a semester in a college level biology course on natural selection at City University of New York. The active-learning class was characterized by fewer misconceptions post course, however both classes exhibited an unsatisfactory understanding of natural selection. In addition to these results seventy percent of the active learning class and eighty six percent of the traditionally taught class employed one or more misconceptions in their explanations of natural selection. These findings confirm that active learning as applied in this study alone does not fully promote conceptual change since neither group exhibited a full understanding as the goal determined.

Podolefsky (2008) investigated the effectiveness of a new model of analogy, Analogical Scaffolding in Colorado, which was described to be specifically tailored toward the challenge of not being able to have students work directly with physics concepts and topics such as electromagnetic waves. The purported results are that analogies as designed in Analogical Scaffolding assist conceptual change by the creation of a learning tool for abstract concepts.

Mevarech (1983) investigated mathematical misconceptions of freshman ($n = 56$) and sophomore ($n = 47$) college students. In addition, an attempt to measure conceptual change an instructional treatment that utilized developmental mathematics master learning strategies (MLS) was performed based on the data received from the initial investigation. Subjects that received the instructional treatment of MLS did significantly better on the summative test, seventy percent of the treatment subjects and forty percent of the control group achieved mastery ($r = 3.20$, $p < 0.01$). These scores exhibited increased achievement and a reduction in misconceptions for subjects that received formative assessment and corrective activities therefore it may be effective for the promotion of conceptual change as a class structure. However, demographic information on subjects did not exist therefore it its uncertain if this treatment would be applicable to all populations of students. With this in mind, Mevarech's findings are consistant to other previously stated findings that state that effective strategies can be recognized by the identification and instruction that directly confronts student misconceptions.

Eaton, Anderson, and Smith (1984) conducted a qualitative and quantitative study to explore the effectiveness of an instructional strategy of science instruction that included design tools to uncover and address students misconceptions formatively and one that did not, in 14 fifth grade classes in the Midwest of the United States with a focus on two classrooms with similar demographics, classroom environment, hands on experience, and textbook.

Of the two classrooms that the study focused the classroom that implemented the instructional design that highlighted a conceptual framework and formative tools contained a higher percentage of students that understood the concept presented, 22 verses 79 percent.

Nakhleh (1990) utilized three treatment groups of equal size they were split into use of chemical indicators, pH meter, and microcomputer interfaced to a pH probe (MBL) to inquire about the possible effects they may have on students concepts of acids, bases, and pH. All three treatment groups exhibited conceptual change, with the MBL group to a significantly greater extent. They authors purported a reason for this outcome based on an unconfirmed attempted explanation of how the use of the computer could have worked with short term to long term memory function. All treatments involved a lab that provided visual representation for phenomena, which could possibly directly confront misconceptions held before the treatments.

A twelve year study of learning of science concepts was performed on first and second grade students (n=191 and n=48) in Ithaca, New York through their twelfth year by Novak and Musonda (1991), and trained graduate students. The treatment group (n=191) received science instruction for first and second grade and the control group (n=48) received no science instruction until later with the treatment group as was traditionally prescribed by the school district during secondary education. Concept maps developed by interviewers utilized open-ended questioning and were scored with a scoring algorithm expressed significantly more valid science concepts in students in the treatment group and fewer misconceptions in grades two, seven, ten, and twelve. However there was not a significant difference in either groups SAT or GPA scores. This was attributed to both the SAT and GPA being based on rote memorization of vocabulary and facts as opposed to science concepts. This study established the possibility that early science instruction that confronted misconceptions led to fewer misconceptions later in life even with similar instructions of more complex science phenomena. This finding is in alignment with other studies that reported the ability for misconceptions to build over time.

Hewson and Beeth (1993), Beeth and Hewson (1997), Beeth and Huziak (2001), Nehm and Reilly (2007), Podolefsky (2008), Mevarech (1983), Eaton, Anderson, and Smith (1984), Nakhleh (1990), and Novak and Musonda (1991) found that in the United States that instructional strategies that required students to engage in higher order thinking skills and metacognition and instructors assessed and directly confronted misconceptions held by there students promoted conceptual formation and change. Such specific strategies included: students' ideas as and integral part of the lesson, conceptual status of ideas should be discussed and negotiated in small and whole group, justification for ideas needs to be explicit, environmental security, mastery of concepts as goals, conceptual instructional framework, student participation in a developmental science community, inquiry based instruction, incorporation of various cultural and mathematical concepts, and early science instruction. An additional aspect to the effectiveness of previously mentioned strategies is the contribution of positive effect on student epistemologies.

Effective Strategies Outside the United States

Ben-Zvi, Eylon, and Silberstein (1986) investigated the preconceptions of tenth graders in eleven chemistry classes throughout Israel ($n \geq 300$), followed by a program to prevent misconceptions and evaluation of the program. All of the students had received at minimum half a year of chemistry instruction prior to the investigation. The results of the evaluation of the new program reported 43.7 percent of the students that received the treatment acquired an acceptable understanding as compared to 18.4 percent of the control group. The authors found that students who had a more complete understanding of the atom also had a more complete understanding of the nature of the compound. These findings are in alignment of the sub section *Links between historical and developmental conceptual development* as the instruction modeled after historical development of the concept successfully promoted conceptual change. The conceptual change exhibited in part of the concept that lead to conceptual change for the larger concept aligns with the findings in the sub section *Development of conceptual change* and results that indicated that agreed upon understandings as well as misconceptions can create a mental framework by which additional knowledge is built upon and filtered through.

Noh and Scharmann (1997) in Korea tested for effectiveness of a Molecular-Level Pictorial Presentation of Matter on Korean high school students' concepts of some fundamental chemistry concepts. Despite this the authors reported that analysis of covariance results expressed that the treatment helped students construct more accurate frameworks, however it did not express any changes for problem solving ability.

Kwon, Lee, and Beeth (2000) in Korea attempted to discover the relation between the level of conceptual conflict otherwise defined as disequilibrium and conceptual change in the student. The demonstration effectively obtained conceptual change more often than logical argument and students with higher conflict levels showed more positive conceptual change. Since demonstration indicated by Kwon, Lee, and Beeth (2000) to maintain higher levels of disequilibrium their findings align with links discussed previously in studies from the other geographic regions of the promotion of conceptual change as driven by disequilibrium.

Sarikaya (2007) in Turkey applied an activity Modeling of the Atomic Structure (MAS) in order to attempt to help challenge pre-service teachers' misconceptions about basic atomic structure in the context of electrification by friction.

Pre service teachers across disciplines held similar misconceptions about atomic structure and friction. Only science disciplines as a whole group and humanities as a whole group showed significant differences in number of misconceptions, subjects in science disciplines had fewer misconceptions ($p<0.05$, $F=1.29$, $p=0.27$, μ^2=0.03). In addition the treatment that utilized the use of models showed significant change in challenging misconceptions of pre service teachers. Since demonstration indicated by Sarikaya (2007) to maintain higher levels of disequilibrium their findings align with links discussed previously in studies, such as Kwon, Lee, and Beeth (2000), from the other geographic regions of the promotion of conceptual change as driven by disequilibrium.

In Perth Australia, Tsui and Treagust (2007) of the Curtin University of Technology assessed the effectiveness on student conceptual change in genetics after an instructional treatment of the computer program BioLogica with a cross-case analysis with conceptual status analysis categories.

As a result of the study the authors concluded that subjects did show significant effectiveness in conceptual change with the multiple representation software in genetics with some variation between individuals even with differences in usage between the three classrooms. These results correlated with previously discussed findings of the effectiveness of treatments shown to directly confront misconceptions as well as the need for various strategies to promote positive conceptual change for all students.

Ben-Zvi, Eylon, and Silberstein (1986), Noh and Scharmann (1997) Kwon, Lee, and Beeth (2000), Sarikaya (2007), and Tsui and Treagust (2007) are among the international researchers that stated that individuals could utilize misconceptions as a framework just as individuals build intellectual frameworks from agreed upon concepts, which they concluded as the rational for confronting misconceptions. Specific strategies the authors stated as successful in the promotion of conceptual change include disequilibrating activities and demonstrations with explicit confrontation of the misconception. In addition it was indicated that the more conflict indicated with the misconception and event or activity the greater conceptual change.

Of the sampling of investigations illustrated in chapter three some included contradictory findings on what was deemed effective. One common aspect of effective strategies described in chapter three and discussed previously in included subjects pre assessment of misconceptions and the use of some pedagogical tool that directly addressed the misconception. In some investigations the use of common misconceptions of the subject matter as reported by findings from previous research and utilized in the design of strategies to directly address those misconceptions also was found effective.

Effective strategy design for directly addressing misconceptions by promotion of conceptual change included kinesthetic manipulations, presentation of contradictory phenomena, instrumentation that created visual representation for phenomena of abstract nature, and open ended questions, in addition to other listed previously in this section. Important to note that no single strategy deemed effective for all students and some strategies have shown contradictory effectiveness.

Contradictory effectiveness could be due to influences other than the strategies themselves. Such investigations described under *Nature of misconceptions, preconceptions, and conceptual change* in chapter three revealed outside influences in their studies. The section indicated environmental, teacher enthusiasm, and other possibly seemingly unrelated influences such as preconceptions that inhibit conceptual change can be a factor in whether or not a strategy is effective on a particular group or individual.

As no single strategy proved effective for any group it can be concluded that the implementation of multiple strategies for the same concept or topic. The use of multiple strategies could allow for more students to gain conceptual change in addition to the possibility of allowance for deeper understanding in students who found previous strategies effective. These possibilities will be discussed further in *Classroom Implications.*

In addition implication of particular strategies proved consistently ineffective and even made conceptual change more difficult for educators to establish. Throughout chapter three the use of rote memorization without also the implementation of pedagogical tools that included complex thinking skills such as those outlined by Blooms Taxonomy. In addition studies also indicated metacognition as effective higher order thinking that promoted conceptual change.

Classroom Implications

Possible practices to incorporate in the classroom include the use of interdisciplinary inquiry based curricula, so all teachers have pedagogical strategies that promote epistemologies of science based more towards inquiry and a body of changing knowledge rather than a stream of facts that they do or don't agree with and thereby reject science as a whole (Abraham, Wiliamson, & Westbrook, 1996; Barlia & Beeth,1999; Beeth & Huziak, 2001; Haidar, 1997; Hadi-Tabassum, 1999; Hennessey, 1999; Kwon, Lee, and Beeth, 2000; McKeachie, Lin, & Strayer, 2002; Nehm & Reilly, 2007; Nakhleh, 1990; Noh and Scharmann,1997; Podolefsky, 2008; Smith, Maclin, Houghton, & Hennesey, 2000; Thompson & Logue, 2006; Tsui & Treagust, 2007). This would also allow for multicultural science such as ethno botany, agriculture, house hold medicines and cleaners, and environmental justice, that would include multicultural contributions to scientific knowledge to allow for all students to have cultural representation in the classroom, and thereby increase student positive epistemologies of math and science. In addition all successful pedagogical practices included: demands of students to employ higher order thinking skills and metacognition, pre and formative assessment of misconceptions in concert with instruction that directly confronted the misconceptions such as disequilibrating events and activities (Barlia & Beeth,1999; Beeth & Hewson, 1997; Beeth & Huziak, 2001; Griffiths & Preston,1992; Haidar, 1997; Hadi-Tabassum, 1999; Hennessey, 1999; Hewson & Beeth, 1993; Kwon, Lee, and Beeth, 2000; McKeachie, Lin, & Strayer, 2002; Nakheleh, 1992; Nehm & Reilly, 2007; Novak & Musonda, 1991; Sarikaya, 2007; Smith, Maclin, Houghton, & Hennesey, 2000; Levin, Siegler & Druvan, 1990).

Conceptually based science starting with early childhood as research (Hennessey, M.G., 1997) has exhibited that young children are capable and show fewer misconceptions later in life (Griffiths and Preston, 1992; Levin, Siegler & Druvan, 1990; Smith, Maclin, Houghton & Hennessey, 2000; Thompson & Logue, 2006). Individuals that receive aforementioned science education will allow scientific thought to be part of their worldview and allow for less conflict with their cultural or faith-based beliefs as long as pedagogical practices do not create negative epistemologies of science(Abraham, Wiliamson, & Westbrook, 1996; De Vos & Verdonk,1987, Fischbein & Schnarch, 1997; Gabel & Samuel,1987; Haidar, 1997; Hadi-Tabassum,1999; Hennessey, 1999; McKeachie, Lin, & Strayer, 2002; Nakheleh, 1992; Robbins & Roy, 2007; Smith, Maclin, Houghton, & Hennesey, 2000).

Suggestions for Further Research

Much of the research gathered used volunteers as subjects, because of these ethical constraints many of the studies provided research on subjects that belonged to privileged or otherwise monocultural groups. it would be helpful to have a wider range of subjects. Possible differences in racial and cultural differences, gender differences, religious or spiritual beliefs, and possible differences with differed learning abilities and styles, for example students with ADHD, autism, and dyslexia would shed light onto what extent specific strategies are effective in heterogeneous classrooms. For instance it would be helpful to know what strategies for the promotion of conceptual change would be effective for students who maintain an extreme negative epistemology of science. Many of the studies examined effective strategies for students who maintained a negative epistemology based on boredom of memorization of facts or a unenthusiastic teacher. It would be helpful to know what strategies would be effective for students who maintain a negative epistemology based on historical oppression or gender norms.

In addition, much of the research gathered was from Korea, Israel, Australia and a couple of Midwestern communities, therefore research in throughout more locations and of various populations would be desired. For instance, comparison studies of cultures that generally hold positive epistemologies and those who hold negative epistemologies would give light the generalibility of specific strategies. In addition, studies in regions of the United States outside such as the coasts, the south and south west as well as Hawaii and Alaska may reveal strategies that are more or less effective based on the culture of the region. This research could be especially enlightening if focused on what misconceptions are altered with life experience and strategies that increase positive epistemologies of science and thereby promote conceptual change.

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