USING TRAINING IN METACOGNITIVE SKILLS (QUESTION STRATEGIES) TO ENHANCE CONSTRUCTIVIST SCIENCE LEARNING

by

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ABSTRACT

Constructivist approaches to education involve giving students the tools they need to assimilate new information into knowledge constructs that they have previously established, modifying those constructs accordingly. The ability to recognize and regulate that process is advantageous in that it gives students the expertise to direct their own learning. Such metacognitive ability can be developed through the use of direct lessons in questioning techniques and subsequent reinforcement through the use of both oral question-and-answer discussions and written questions, as well as oral and written responses. Thus, a series of lessons were conducted in order to instruct seventh grade students in the identification of types of questions, relevant signal words, and a rubric for coding depth and complexity of questions. It was hypothesized that the lessons in question strategies would result in higher level questions posed and answers given as well as higher summative assessment scores and an increase in student confidence in science class. The rubric was used to codify questions and answers collected through a variety of means. Specifically, prior to and following the intervention, students used anonymous exit slips to ask questions about content; coding showed that students asked higher level questions after being taught question strategies. Oral questions, culled from transcriptions of audio-recorded classroom discussion, also showed higher level questioning in the post-intervention unit. Answers transcribed and coded from audio-recordings did not show much improvement, but written reflective answers did show higher level responses from pre- to post-intervention units. Summative test scores weakly supported the study's objective in that scores improved from 2011 to 2012 seventh grade classes, and there was considerable improvement in performance on one question targeted at a misconception problem. Finally, students did show a confidence increase from the pre- to post-treatment units as assessed by means of a Likert-type survey and interviews.

INTRODUCTION AND BACKGROUND

Context and Problem Statements

Demographics

The focal group for this study is seventh graders at Seton Catholic School, an independent K-8 Catholic school located in Hudson, Ohio, an affluent suburb of Cleveland. The school has grown in 14 years from 60 to 434 students. 62% of Seton students are residents of Hudson; the remainder is drawn from 18 neighboring communities in three counties. 92% are Catholic, and almost 75% are white; all are native speakers of English. Approximately 75% of Seton students scored above average when comparing them to the national stanines for the 2011 Iowa Tests of Basic Skills. These facts are indicative of many gifted students and also, often, of very involved parents; many students are the children of professionals. Most eighth graders move on to college preparatory high schools (many Catholic); their alternative is Hudson High School which is one of the best public high schools in the state. In general, Seton students are motivated by grades and want to do well in school.

Problem Statements

The seventh graders at Seton were selected for metacognition training because students of their age are arriving at a developmental cognitive transition in which they are beginning to recognize that there are multiple perspectives from which individuals may view problems and consequently, multiple means by which they might solve problems. This relativist approach – in which students recognize that there are alternative forms of knowledge, and all knowledge is treated as equally valid – sets students of this age on a

path toward critical thinking (Kuhn & Dean, 2004). Necessary, however, is guidance and direction in constructing and evaluating knowledge. The researcher/writer teaches sixth, seventh, and eighth grade science and is uniquely placed to scaffold science education in such a way that sixth graders learn to assimilate information, seventh graders can integrate information, and eighth graders can develop their cognitive and metacognitive independence.

Seventh graders, no matter how seriously they consider their educations, are ill-equipped to assess their own academic skills without explicit instruction. While their cognitive abilities are developing, their metacognitive abilities will not keep apace unless their teachers teach them to recognize their skills, habits, weaknesses; in other words, it is the job of teachers to help students identify their individual approaches to learning. Thus, the goal of this research is to direct the development of metacognitive skills to help seventh graders construct knowledge in order to enhance conceptual understanding and increase success their on summative assessments. A secondary goal is that as students facilitate their academic success, they concomitantly increase in self-confidence.

Research Questions

My interest in helping students learn to monitor their own learning led me to ask the following question: In what ways does metacognitive training impact student scientific conceptions and thus summative assessment scores and attitude toward science learning?

More specifically, I have broken that primary question down into a series of secondary questions as follows:

- With direct training in questioning techniques, do student begin to ask higher level questions?
- With direct training in questioning techniques, do students begin to give higher level answers?
- Do summative assessment scores improve with the development of metacognitive skills?
- Do students' attitude, self-confidence, and autonomy toward science improve with training in metacognitive skills?

CONCEPTUAL FRAMEWORK

Constructivism

The constructivist or knowledge integration theory of cognition holds that students must build their understanding of concepts. In order to construct knowledge representations, students are best served if they are able to monitor and evaluate their own efforts. Thus, explicit instruction in metacognitive strategies can help students develop their cognitive skills and improve their classroom achievement. Some strategies that help students to self-assess include asking questions, reflecting via prompt-responses, and building portfolios. In addition to using portfolio development to build metacognitive skills and cognitive success, it can also engender engagement and self-confidence.

Knowledge integration begins when a student receives material, for example, in a classroom setting. The student then activates prior knowledge (Appleton, 1997) in order to expand his repertoire of ideas (Davis, 2003). It "begins with an active and engaging

process that provides an opportunity for the learner to create meaning from an experience" (Llewellyn, 2007, p. 56); students "learn how to create knowledge [in order to] acquire knowledge" (Dyasi in Annenberg Learner, 2000). As the student begins to link new ideas with existing ones, he may identify discrepant events which lead to cognitive conflict (Appleton, 1997; Davis, 2003). At this point, students diverge in their response with some simply focusing on concrete aspects of the problem, limiting themselves to surface processing (Appleton, 1997). Others conduct deeper processing, making comparisons and analogies and beginning to construct new conceptions (Appleton, 1997). The new construct may complement a student's prior knowledge and may be adopted as a new, more developed construct. However, it may also be that the new idea does not fit the student's initial understanding, and he consequently disregards the new information; misconceptions often perpetuate because a student is not able to reconcile different knowledge constructs (Blosser, 1987; Appleton, 1997). Misconceptions can stem from daily experience, media, or previous classroom experiences (Blosser, 1987; Llewellyn, 2007). In order to integrate knowledge, simply identifying a discrepancy is not sufficient (Davis, 2003), nor is simply modeling metacognitive processes (Lin, 2001). Thus, a goal of educators must be to achieve conceptual change (Blosser, 1987), identifying and confronting misconceptions (Blosser, 1987; Llewellyn, 2007; J. Graves, lecture notes, 2011) and helping students "create and improve ideas," by analyzing their own conceptions as well as learning to use scientific ways of thinking (Lee, Chan, & van Aalst, 2006, p.280).

The construction of knowledge is a social process in which collaboration allows students to integrate a variety of ideas and perspectives and "advance a community of

knowledge (Lee, Chan, & van Aalst, 2006, p. 280)" while also developing self-concept relative to social context (Lin, 2001). The distributed and collective nature of cooperative learning allows students to construct a shared understanding of goals and concepts (Hall & Hewitt-Gervais, 2000; Lin, 2001; Lee et al., 2006). For example, Clark, Choy-Hoy, Herter, and Moss (2001) describe portfolio building as a "distinctly social (p.212)" process, engaging students collaboratively in the development and revision process. Ciardiello (1998) describes "socially mediated strategies … [in which] … skill development depends on the services of others (p. 10)." Engagement is defined by Clark et al. (2001) as the state in which a learner is motivated, participatory, and integrated into the setting and tasks. They were able to document higher performance when students were engaged, working towards goals that were personally meaningful. Thus, active, collective knowledge integration results in advanced cognition and, thus, students who become adept at constructing experience into scientific conceptions.

Metacognition

The task of educators, consequently, is to help students to develop their epistemological outlook. According to Kuhn and Dean (2004), the developmental nature of thought begins with the realist (the toddler for whom knowledge is a copy of reality); for the realist, critical thinking is unnecessary because knowledge is certain. The absolutist is over the age of four and is a collector of facts; knowledge is completely objective. Once students, usually in adolescence, begin to recognize that people disagree about knowledge, they modify their world view to a multiplist or relativist view in which knowledge consists of "opinion, freely chosen by their holders as personal possessions and accordingly not open to challenge (p. 274)." At this stage, one at which some adults

may remain throughout life, critical thinking is irrelevant because everyone has a right to his own opinion, so all opinions are equally correct. It is only at the evaluativist level that critical thinking is valued, for it is at this epistemological level that the thinker understands that knowledge constructions can be compared and should be supported by evidence. Since this is not a stage at which each person necessarily arrives in due course, it is incumbent upon the educator to model critical thinking skills and to teach them overtly.

In addition to the facility with which a student is able to evaluate constructs against available evidence, students vary in the degree to which they are willing to make the effort to do so. Influencing their efforts are certain beliefs about themselves that students use when approaching tasks; these are elucidated by Davis (2003): Students vary in the degree of autonomy which they exhibit with regard to who they think should manage their learning; they range from those who accept personal responsibility to those who attribute responsibility to others, e.g., parents or teachers. In fact, Davis found that learners who were described as low in autonomy scored low for a task coded for coherence and that learners who were ranked in the middle of the autonomy continuum appeared to benefit the most from training in metacognitive strategies (while those scoring the highest for autonomy were consistently successful with or without the strategy training).

Metacognition, then, refers to the awareness and management of one's thoughts and learning (Kuhn & Dean, 2004). Designing classroom activities in order to help students build metacognitive strategies involves designing activities that capitalize on students' prior experience, autonomy, and developmental/epistemological status (Blosser,

1987; Appleton, 1997; Ciardiello, 1998; Schraw, 1998; Hall & Hewitt-Gervais, 2000; Clark, Chow-Hoy, Herter, & Moss, 2001; Lin, 2001; Davis, 2003; Kuhn & Dean, 2004; Lee, Chan, & van Aalst, 2006, Llewellyn, 2007). Student success in learning science is the product of what both the students and the teacher with curriculum bring to the classroom (Lee & Anderson, 1993). In order to integrate metacognition training into domain-specific contexts, some basic design principles can guide the educator. A list proposed by Lin (2001) includes:

- Giving students frequent opportunities to self-assess
- Helping students to articulate their own thinking
- Fostering a shared understanding of goals (i.e., building the community aspect of constructivist teaching)
- Helping students to develop knowledge of themselves as learners (p. 34)

Hence, the educator's task is to implement various strategies that suit the needs of his students and that also direct the students in sense-making (Davis, 2003) or knowledge integration (Lee & Anderson, 1993; Appleton, 1997; Ciardiello, 1998; Schraw, 1998; Clark et al., 2001; Lin, 2001; Davis, 2003; Kuhn & Dean, 2004; Lee et al., 2006, Llewellyn, 2007) as well as constructing an understanding of self-as-learner (Lin). Collaboratively building concepts also develops the students' sense of engagement and identity in the context of a learning community (Clark et al., 2001). School work "becomes more authentic as students can actually influence the course of their work (Clark et al., 2001, p. 235)." If students explicitly understand the rationale for using a particular strategy, they are more likely to employ that strategy (Ciardiello, 1998).

Metacognitive strategies should be taught directly as well as being modeled by both teachers and other students, sharing cooperatively (Lin, 2001). Such strategies can be categorized as having as their goal monitoring, evaluating, or regulating thought. Self-monitoring strategies may include clarifying information and questioning (Ciardiello, 1998), error-detecting, elaborating, constructing a visual representation, re-reading, and explaining instructions to one's self (Lin, 2001), and self-testing (Schraw, 1998). Any of these strategies can be applied to encourage students to stop and think in order to activate and integrate knowledge.

Self-evaluation strategies can include activities such as summarizing (Ciardiello, 1998), arguing (Kuhn & Dean, 2004), assessing, explaining, detecting errors (Lin, 2001), or diagnosing weaknesses (Schraw, 1998). Thus, students develop awareness of comprehension breakdowns (Schraw, 1998) in order to redress those lapses and develop skills in broad thinking (Kuhn & Dean, 2004), problem-solving (…), "linkedness" and coherence of understanding (Davis, 2003, p.120). Furthermore, identifying one's accomplishments encourages students to have pride in their work, cyclically improving their self-perception of ability and encouraging them to expend more effort (Van Kraayenoord & Paris, 1997). Clark, Chow-Hoy, Herter, and Moss (2001) also found that self-evaluation resulted in increasing confidence and self-esteem.

Metatcognitive strategies used to enhance self-regulation include planning (Schraw, 1998), revising (Lin, 2001), allocating of resources such as time, effort, and/or attention (Schraw, 1998; Lin, 2001) predicting, sequencing strategies (Schraw, 1998), and correcting mistakes (Van Kraayenoord & Paris, 1997).

Appleton (1997) found that students who used metacognitive strategies to attempt to clarify discrepant ideas gained more information and used that to process the new construct at a deeper level, iteratively building more comprehensive cognitive constructs. In fact, teachers' deliberate introduction of discrepant events may generate student wonder and thus motivate students to develop their own questions and conceptions (Llewellyn, 2007; J. Graves, lecture notes, 2011). Schraw (1998) asserts that student performance improved when students were taught to recognize comprehension breakdowns and resolve them. Van Kraayenoord and Paris (1997), Hall and Hewitt-Gervais (2000), and Clark et al. (2001) demonstrated that students whose literacy portfolios gave evidence of conscientious construction, revision, and self-assessment were more engaged in school, developed better cooperative skills, and were more motivated to succeed. Van Kraayenoord and Paris (1997) also speculated that students were more purposeful learners when they understood and could self-regulate according to curricular standards and performance standards. Davis (2003) showed that students who used prompts to produce innovative and scientific reflections also developed high level critiques and products that were coherent. Finally, Lee, Chan, and Van Aalst (2006) demonstrated much higher scores for depth of inquiry (in questioning) and depth of understanding (in answering/explaining) for students who were given direct instruction in knowledge-building metacognitive skills like the ones identified below.

Two specific strategies that an educator can teach to students are questioning skills (for the purpose of monitoring learning and planning ahead) (Ciardiello, 1998; Lee, Chan, & van Aalst, 2006) and self-reflection via prompts (which can be modified in various ways to encourage monitoring, evaluation, or regulation of learning). Ciardiello

(1998) identifies four types of questions and outlines a protocol for training students to develop high level questions because he asserts that generating questions helps students to think and communicate. Questions can be organized into four categories as follows. **Memory questions** involve cognitive operations such as defining, identifying or designating. **Convergent questions** involve relating ideas in such ways as comparing, contrasting, or explaining. **Divergent questions** are open-ended and involve predicting, hypothesizing, and inferring. Finally, **evaluative questions** require judgment and justification of choices. One can easily relate these question categories to the developmental and epistemological status of more and less sophisticated learners and to Bloom's famous developmental taxonomy. Ciardiello (1998) found that his question training (developed over many years of teaching in inner city schools) gave students control of their cognitive accomplishments and increased their motivation. Reflective expression can be written (Schraw, 1998; Hall & Hewitt-Gervais, 2000; Clark, Chow-Hoy, Herter, & Moss, 2001; Lin, 2001; Davis, 2003; Kuhn & Dean, 2004; Lee, Chan, & van Aalst, 2006) or can be investigated via interview (Appleton, 1997; Van Kraayenoord & Paris, 1997; Hall & Hewitt-Gervais). Providing students with a set of specific criteria can help them to assess their own attempts to develop cognitive skills; this is the essence of metacognition. Schraw presents a Regulatory Checklist (RC) that enables students to assess and regulate their learning. The RC consists of three metacognitive categories and four self-management questions that a student can use to self-assess. See Table 1 below.

Table 1
Regulatory Checklist

Planning
What is the nature of the task? What is my goal? What kind of information and strategies do I need? How much time and resources will I need?
Monitoring
Do I have a clear understanding of what I am doing? Does the task make sense? Am I reaching my goals? Do I need to make changes?
Evaluating
Have I reached my goal? What worked? What didn't work? Would I do things differently next time?

Note. Adapted from Schraw, 1998, p. 121.

Lee, et al. (2006) developed a set of self-monitoring categories for use by students when evaluating their electronic portfolios. The list is designed to provide prompts for portfolio reflections and can be found in Table 2.

Table 2
Self-Monitoring Categories

• working at the cutting edge
• progressive problem-solving
• collaborative effort
• monitoring own knowledge
• constructive use of authoritative sources

Note. Adapted from Lee, Chan, & van Aalst, 2006.

Prompts used to elicit written reflective responses can fall easily into two categories, directed and generic. Most authors describe the use of directed prompts as scaffolds for learning (Schraw, 1998; Lin, 2001; Davis, 2003; Lee, Chan, & van Aalst, 2006), designed to help students monitor or evaluate their progress, plan ahead, and construct knowledge. Students are asked questions or given sentence starters that are

designed to trigger particular metacognitive processes as well as to demonstrate cognition. Davis (2003) inserted prompts into a series of activities; she summarized her directed prompts for reflection into three categories: Checking Our Understanding [monitoring], Thinking Back [monitoring, evaluating], and Thinking Ahead [planning]. However, she contrasted directed prompts with generic prompts which took the form of "Now we are thinking …" to which students could make a response that integrated their current thoughts, rather than requiring a redirection (as may often be necessary in responding to a directed prompt). Davis (2003) found that the generic prompts elicited a broader range of ideas and greater coherence in the final product; she found that students receiving generic prompts "engage[d] in more potentially useful activities" (p. 116).

Reflective responses can be used by others to assess the success of various teaching strategies, including the explicit instruction of metacognitive strategies, and to identify cognitive and metacognitive functions of students. They can make student thinking "visible" (Williams, Linn, Ammon, & Gearhart, 2004). Various authors have developed coding schemes to be used for these purposes. For example, Lee and Anderson (1993) coded responses according to four criteria identifying whether students learned scientific concepts as intended by the teacher, made nonscientific responses, produced a response that was a combination of the first two, or produced an ambiguous response. Van Kraayenoord and Paris (1997) developed a question set designed to elicit students' responses to their classroom experience. The questions addressed issues of pride, assessment of difficulty, self-review, personal progress, literacy ability, social aspects of learning, and goals for future development. They developed a 3-point coding scheme that ranked students' responses according to whether they evidenced depth of

insight, explanation, and self-evaluation. They found developmental and gender trends such that older students and female students showed increasing sophistication of response. Davis (2003) developed a coherence coding scheme (mentioned above) whereby student reflections received scores of 0-5 depending upon whether the response was incoherent, had some connection to a canonical scientific concept, showed adequate understanding, excellent understanding, or exceptional understanding and linkages to evidence. Additionally, Davis (2003), coded responses for their focus, identifying reflection on general actions and goals, project activities, project ideas, knowledge monitoring and understanding, and "no problem" responses (those in which students indicate no changes or problems). As mentioned above, she found that greater coherence scores correlated with frequent knowledge monitoring activities; interestingly, she also found that students who gave "No problem" types of responses appeared to misjudge their own understanding and concomitantly received lower scores on work quality. Lee, Chan, and van Aalst (2006), finally, coded for depth of inquiry (a 4-point scale for questions) and understanding (a 7-point scale for answers) such that student work was evaluated on the basis of its complexity and relationship to evidence. They also developed a 6-point portfolio rating scheme, judging portfolio contents on the basis of both the contents and the students' explanation of the contents. They were able to demonstrate that higher scores correlated with the research condition in which students received training in metacognitive skills (rather than simply requests for reflective responses).

Portfolio Development

Much of the research cited herein is based on materials collected from student portfolios. The actual contents of portfolios vary according to the culture of a particular classroom with both the needs/goals of the educator and the students informing the types of materials included (Clark, Chow-Hoy, Herter, & Moss, 2001). Thus, portfolios are described by Clark et al. (2001) as "dynamic sites of learning" (p. 233) in which students can construct, compile, document, share, revise, reflect or assess their learning. Thus, students are actively involved in constructing their own knowledge; again, the authors emphasize that the collaborative nature of building and revising a literacy portfolio contributes to the community-building aspect of constructivist education practices. Hall and Hewitt-Gervais (2000) refer to the process approach to learning that portfolios exemplify. Lee, Chan, and van Aalst (2006) assert that portfolios capture the "distributed nature of cognition" (p. 302) in which students integrate content and process, employing a constructivist framework.

Despite the variability, there are some common elements to portfolios. They provide an ongoing, tangible record of accomplishment as well as evidence that a student's work is valued. They provide opportunities for students to reflect upon their work (as described above) (Clark, Chow-Hoy, Herter, & Moss, 2001). Portfolios are also a useful tool for conferencing between teachers and students, parents, or other teachers particularly with the intent of identifying student strengths and weaknesses (Hall & Hewitt-Gervais, 2000; Clark et al., 2001). Hall and Hewitt-Gervais (2000) also point out that teachers can use portfolios to evaluate instructional techniques and implement changes as necessary. Finally, portfolios provide a mechanism for compiling and

organizing materials that have been used for metacognitive purposes as described above. Thus, an individual student's portfolio may contain work samples (self- and/or teacher-selected), examples of questions developed to further concept construction, and reflection (generated in response to directed or generic prompts) which may serve the purpose of monitoring, evaluating, or planning knowledge-building.

One caveat that should be noted is the concern noted by Johnston (2004) that there is difficulty in scoring portfolios based on inconsistencies in rater reliability. In addition, she raises the issue of the validity of scoring a portfolio holistically (thus conflating a variety of types of materials) as opposed to atomistically (in which the scores are not qualitatively different from simply assigning grades to student work). The author concludes that portfolio assessment should be formative only, not summative.

Authentic learning takes place when students are engaged in the classroom environment, participating in the processes of receiving and integrating new information, collaborating with their peers, and learning to explicitly manage their own thoughts and ideas. Actions of this type do not occur without encouragement and instruction from educators who develop an atmosphere of collaboration and who design activities that help students to access and manage their cognitive processes. The development of portfolios is an effective method of managing materials including those that reflect metacognitive strategy-training.

METHODOLOGY

As the goal of this study was to develop seventh graders' metacognitive skills, students received training in one particular skill, developing their questioning strategy.

To this end, they participated in a series of lessons directing them to identify different types of questions including signal words for different question types, write different types of questions, and code questions for complexity of thought. Questions and responses were collected and coded from a unit of study (electricity) preceding the question lessons to serve as a baseline; these can be contrasted with those collected during the unit of study (meteorology) following the intervention.

Demographics

Seventh graders were chosen as participants in this study for two reasons. As the middle school science teacher, I thought that they would be more adept at introspection than the sixth graders I teach; in addition, they would still be available for follow-up and development as eighth graders, whom I also teach. There were two seventh grade classes, and those were leveled for math ability; science was the class that was scheduled opposite seventh grade math, so the science classes were necessarily leveled as well. There were 25 students in the accelerated math group; those students were taking pre-algebra. There were 18 students in the mixed ability math group. Included in the latter group were the lower level math students, three students who were new to the school (abilities unassessed prior to the academic year), and two highly accelerated math students (taking algebra); thus the latter group was more diverse.

Most of the seventh graders were from Hudson and surrounding communities, although one commuted an hour-and-a-half each way to attend Seton. Most were white, although one was Indian and spoke Telegu at home. Most were Catholic with the exception of three, two of whom were Protestant and one who was Hindu. Two students

in each class were receiving medication for ADHD and one, in the mixed ability class, had Asperger's syndrome. To my knowledge, all had supportive families and middle class or higher income levels.

Both science classes were being taught the same material on the same schedule. In both classes, students were seated in pairs at two-person lab tables (except in the higher level group in which one student was a third at her table). Considerable attention was given to each seating plan in order to capitalize on student support structure, such that, students were paired with people with whom they could work productively. Lower students, thus, received support, while higher ones had the opportunity to teach their peers to varying extents; students who conflicted with one another or who over-stimulated one another were kept apart. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. One student was not given parental permission to participate in the study and thus is not included in survey data and was not recorded.

Project Design

In designing this study, I set out to examine ways in which I could help students to identify and monitor their own knowledge. It was my contention that if students were taught to recognize their own conceptions, they could better regulate and construct ideas and plan their future actions. As a consequence of controlling aspects of their own learning, I hoped to see improvements in their scores on summative assessments as well as in their confidence and positive outlook toward science. In other words, I hoped to

determine whether metacognitive training impacted student scientific conceptions and thus summative assessment scores and attitude toward science learning.

The idea of self-reflection was not unfamiliar to my students as they had engaged in a number of reflective activities since the school year began. These included responses customized to graded work, usually lab activities. The responses were usually a series of survey statements, e.g., "I was able to identify the variables in this lab … _ yes, _ sort of, ___ no" and/or short answer queries, e.g., "My best definition of the term 'inference' is … ." Furthermore, I had developed a checklist of lab skills that were initialed by students and myself when mastery of a particular skill (e.g., converting values within the metric system or identifying dependent and independent variables) had been demonstrated. An additional means of self-reflection in which students participated was an online multi-intelligences self-assessment (*Assessment: Find Your Strengths*): Each student did the survey online and printed the analysis. Following a series of small-group and full-class discussions, students selected three strategies to try on their own. Later prompts were supplied to determine whether students had tried their intended strategies and how they felt about the attempts. My action research reflections, contrary to these other reflections, required prose responses constructed to require thoughtful short answer responses or thoughtful questions.

I implemented my research in the context of a unit focusing on meteorology which I was able to compare to a pre-treatment unit on electricity as well as to some artifacts from the meteorology unit of the prior academic year. Meteorology was chosen as the treatment unit because I discovered misconceptions during the prior academic year that I planned to confront and help students to reconstruct. Teaching explicit lessons in

the characterization of questions and questioning techniques prior to the meteorology unit provided the direct intervention that allowed me to direct metacognitive development throughout. With such training, would students' questions increase in depth and complexity? Would their answers to questions show evidence of greater sophistication, suggesting that students were planning, revising, or self-monitoring their conceptions? In tandem, would summative assessment scores improve with the development of metacognitive skills? Furthermore, as students gained greater insight into their own learning, would they increase in confidence and autonomy; would their attitude toward science class become more positive?

There are three subsections to follow. The first is the question lessons that were implemented before the treatment unit and provided the metacognition training. The second describes the interventions that were used with the meteorology unit. The baseline data will be described third and in comparison to the treatment unit.

Intervention – Question Lessons

Following the electricity unit, I introduced a skills digression (an experience with which these students were familiar) in order to teach the lessons on question types and techniques. The student worksheets for the question lessons can be found in Appendix F. Following Ciardiello (1998), questions can be memory, convergent (relabeled relational), divergent (relabeled inferential) or evaluative in nature (see Table 3 for the list of question types, the cognitive operations they indicate, and some example signal words). I relabeled convergent and divergent questions in order to make the labels more transparent for seventh graders to understand; they had a rudimentary understanding of relation and

inference and thus, would not need to learn the concepts of convergence and divergence while they were also learning about question recognition and coding. Each type of question makes progressively more demands on both questioner and the responder in terms of cognitive load; they are developmental in nature, challenging the interlocutors to increase their critical thinking skills, mirroring the epistemological stages described by Kuhn and Dean (2004), the realist, absolutist, relativist, and evaluativist ways of thinking.

Table 3
Ciardiello's (1998) Question Types and Cognitive Operations with Signal Words

Question Type	**Cognitive Operations with Signal Words**
Memory	Naming, defining, identifying, designating; yes/no responses Signal words: *who?, what?, where?, when?*
Convergent thinking [Relational]	Explaining, stating relationships, comparing & contrasting Signal words: *why?, how?, in what ways?*
Divergent thinking [Inferential]	Predicting, hypothesizing, inferring, reconstructing Signal words: *imagine, suppose, predict; if …then, How might?, What are some possible consequences?*
Evaluative	Valuing, judging, defending, justifying choices Signal words: *defend, judge, justify, What do you think? What is your opinion?*

Note. Adapted from Ciardiello, 1998.

Students were first given a list of question types (although, again, Ciardiello's terms 'convergent' and 'divergent' were relabeled as 'relational' and 'inferential'), cognitive operations, and signal words; the question rubric was included as well; see Table 4 and also Appendix F. For each operation, example sentences were provided

(Ciardiello). As a pair-share activity, students developed two more questions for each type of operation; these were turned in for my perusal.

Table 4
Student Summary Sheet – Question Types, Signals, and Coding

Question Type	**Cognitive Operations with Signal Words**	**Question Code**
		0 - unclear
Memory	Naming, defining, identifying, designating; yes/no responses Signal words: *who?, what?, where?, when?*	1A – Logistical (how to do something) 1B - Factual
Relational	Explaining, stating relationships, comparing & contrasting Signal words: *why?, how?, in what ways?*	2 - Relational
Inferential	Predicting, hypothesizing, inferring, reconstructing Signal words: *imagine, suppose, predict; if …then, How might?, What are some possible consequences?*	3 - Inferential
Evaluative	Valuing, judging, defending, justifying choices Signal words: *defend, judge, justify, What do you think? What is your opinion?*	4 - Evaluative

The next step involved classifying questions: Each student received a question on a strip of paper; one by one, they affixed each strip to the whiteboard with tape according to the correct question category together with a brief justification by the student assigned the question; discussion ensued whenever there were miscategorized questions. Follow-up discussion focused on understanding the purpose and value of generating questions.

"Question generation is both a cognitive and metacognitive strategy … because the process of asking questions enhances comprehension through a focus on main ideas (content) and also checks understanding to see if the content is learned" (Rosenshine et al. quoted by Ciardiello, 1998, p. 213).

The third question lesson involved categorizing questions and answers according to the coding rubric that I had already been using for evaluating student questions and answers during the electricity unit; see Appendix A. The question coding categories are: Zero(0) Ambiguous (for questions that are incoherent or a statement such as, "I have no problems; I understand everything."); one A(1A) memory - logistical (questions that refer to what to do or how to do it); one B(1B) memory - factual (seeking topical or general information); two(2) relational (exploring relationships among ideas or concepts, Ciardiello's convergent); three(3) inferential (open-ended, identifying comprehension gaps, involve planning, Ciardiello's divergent); four(4) evaluative (pursuing possible explanations to problems). Both logistical and factual questions fit into Ciardiello's (1998) memory question type; the latter three match Ciardiello's categories, and all coordinate with Williams, Linn, Ammon, and Gearhart's (2004) coding scheme (logistical, factual, conceptual) and that of Lee, Chan, and van Alst's (2006) system (clarification, factual, open-ended, and explanation-based). Students worked in pairs to code questions. We then discussed as a group questions, concerns, and discrepancies.

Although students did not see the answer coding rubric, it was developed in parallel with the question rubric, using Davis (2003) (incoherent, somewhat canonical, adequate understanding, understanding, evidence included) and Lee, Chan, and van Alst (2006) (restatement, factual, inferential, explanatory, synthetic) as the foundation. The

answer codes consist of zero(0) ambiguous/incoherent; one(1) memory (logistical and factual); two(2) relational (explanation, comparison); three(3) inferential (showing evidence of making inferences, connecting concepts); and four(4) evaluative (answers that synthesize viewpoints and/or show judgment). Table 5 relates the question rubric, the answer rubric, Ciardiello's (1998) foundation, and Kuhn and Dean's (2004) epistemological levels. Answers were coded in this manner in order to determine whether students transferred the metacognitive training in questions to their responses to questions.

Table 5
Question and Answer Coding Matrix

Ciardiello (1998) Question types	Kuhn & Dean (2004) Epistemological Levels	Question Rubric	Answer Rubric
		0 – Ambiguous	0 – Ambiguous
Memory	Absolutist	1 – Memory	1 – Memory
Convergent	Relativist	2 – Relational	2 – Relational
Relational (Divergent)		3 – Inferential	3 – Inferential
Evaluative	Evaluativist	4 – Evaluative	4 – Evaluative

Finally, the fourth question lesson incorporated the knowledge developed in the previous three lessons. As a class, we read a selection aloud (included in Appendix F). After each paragraph, each pair of students wrote a question from each question category. At the conclusion of the selection, student pairs were to exchange questions with an adjacent student-pair who scored each question according to the question rubric, requiring that students apply the lessons developed throughout this set of lessons.

In conjunction with these lessons, a classroom poster was displayed which reproduced the question information that students received (question types, operations, signal words, and coding rubric). Thus, the lessons remained prominent, encouraging students to continue to consider them during the remainder of the academic year. The answer-coding rubric was not posted, nor did students have any exposure to it.

Data Collection Instruments

Treatment Unit – Meteorology

In order to determine whether my intervention had the desired outcomes, I coded oral class discussion and written responses from both the pre-treatment electricity unit and the meteorology unit for depth and complexity and for evidence of developing sophistication in thought. I used exit slips eliciting questions (e.g., "muddiest points" or relating content to other experiences) at the end of classes in which new information was presented; by their nature, these were anonymous. I used oral class discussion as a reteaching tool via predetermined questions; these discussions were audio-recorded (see Appendix H), and transcribed in their entirety. Finally, prompts for written portfolio reflections were used following reteaching and lab activities; these used a response-seeking format (included in Appendix I). These were collected in the reflection portfolios, as were the electricity responses, designated for each student. These remained separate from the students' regular portfolios which contain graded work with the targeted reflections, multi-intelligences assessment, work habits reflections, and skills checklists; these were to go home with students in June. Note that students themselves maintained a binder in which all notes, worksheets, and some labs were kept available for study; the materials that remained in the portfolio were less accessible and thus not the

materials most useful for studying for tests. A reflective teacher journal was used to record observations and insights as well.

I interviewed six students about their feelings toward the question training, their comfort level with the questioning techniques, and whether they thought that the training would be helpful to them in learning science; interviews were conducted immediately following the question treatment. Interview questions appear in Appendix G. I selected three boys and three girls for interviews, one of each who generally received high marks in science and seem confident with the material, one of each who typically scored low, and one boy and one girl who ordinarily scored in between the extremes.

Extended response questions from summative assessments from the pre- and post-treatment units (electricity and meteorology, respectively) were used for comparison and were scored for accuracy; see Appendix J for the questions. My objective was to determine whether students wrote more insightful test responses having had multiple reflective experiences and training in developing and analyzing effective questions. In addition, the summative assessments for meteorology from the current seventh grade classes (2012) could be compared to those of the previous seventh grade (2011); overall scores were compared as well as targeted questions that referred to misconceptions identified during the 2011 meteorology unit (see Appendix K). The latter consisted primarily of multiple choice questions; the identical questions were used in 2011 and 2012 to allow for direct comparison.

Prior to introducing the question lessons and again after the meteorology unit, the students completed a survey, assessing their attitude, confidence, autonomy, and metacognitive awareness in science; each category was represented by 25% of the

questions in random sequence (Appendix D). The paper surveys were conducted during class; the student whose parents opted out of the survey was encouraged to read her Accelerated Reader novel while waiting for her classmates to complete the survey. Additionally, some students were interviewed about their confidence, effort and attitude toward science class; the students selected were the same as those interviewed about the question lessons. The interviews took place prior to the intervention and at the conclusion of the treatment unit and were conducted over lunch in the science classroom. Interview questions can be found in Appendix E. Finally, the meteorology test reflections from each year were compared. In those, students were asked, in checklist format, to indicate which learning materials were most useful to them. While the question and answer treatments were not used in 2011, other methods could be compared (Appendix L). These also gave an indication of confidence and autonomy in learning.

Baseline Data - Electricity

The unit preceding meteorology dealt with electricity. In that unit I collected baseline data: exit slips (questions), student questions (from oral discussion), student answers (also from both oral discussion and written responses to prompts), short answer responses in the summative assessment (see Appendix J for the test questions), and the student confidence survey and interviews mentioned above. The coding rubrics found in Appendix A were used for questions and for answers. See Appendix B for the predetermined questions used in designated classroom discussions; these were audio-recorded. All written responses were introduced with instructions to write “good” questions or to answer predetermined prompt questions (see Appendix C) and were collected in the research portfolios.

The triangulation matrix in Table 6 summarizes the research questions and the data collection instruments used to address them.

Table 6
Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question: In what ways does metacognitive training impact student scientific conceptions and thus summative assessment scores and attitude toward science learning?			
Secondary Questions:			
Training in questioning techniques: Do students begin to ask higher level questions?	Exit slips from pre-and post-treatment units: Q/A coding rubric	Class discussion; Q/A coding rubric	Class discussion; in-depth question clarifications and extensions
Training in questioning techniques: Do students begin to give higher level answers?	Written reflective answers from pre- and post-treatment units; Q/A coding rubric	Written reflective answers from pre- and post-treatment units; in-depth answer clarifications and extensions	Class discussion; Q/A coding rubric
Do summative assessment scores improve with the development of metacognitive skills?	Targeted misconception questions from 2011 compared to 2012 (Also, misconception probe from 2011 classroom lesson)	Scores from 2011 seventh grade compared to 2012 (post-treatment)	Extended response scores from pre-treatment unit compared to post-treatment unit (current seventh grade)
Do students' attitude, self-confidence, and autonomy toward science improve with metacognitive training?	Pre- and post-treatment student surveys	Student interviews	Test reflections (check-lists): student opinions about useful learning tools, 2011 compared to 2012

DATA AND ANALYSIS

The pre-treatment electricity unit was conducted in December and January, spanning the New Year 2011 into 2012. The intervention, the question lessons, took place in January. Finally, the post-treatment meteorology unit was introduced in early February, concluding with the summative assessment dealing with its foundation (air pressure, heat transfer, elevation, and the water cycle) which took place on March 15, just prior to a one-week spring break. After a brief discussion below about the question treatment itself, each research question will be addressed, student questions, student answers, summative assessment comparisons, and finally, student attitudes toward science learning.

Question Treatment

The question lessons themselves were introduced with the definitions of 'cognition' and 'metacognition;' I explained to the students that cognition is thinking but that metacognition is "thinking about thinking." I further explained that when we learn something new or study for a test, it is important to "know what we don't know;" this helps us to figure out where the gaps are in our understanding of an idea. This was not an unfamiliar idea to my students, and they were also receptive to doing something new in class. Neither Question Lesson One nor Two was collected; One was the students' first attempt at writing questions in each category, and Two involved categorizing questions in the context of class discussion. These collaborative lessons allowed everyone to familiarize themselves with the task at hand and engendered discussions about the

question categories as well as exemplars of particular questions. The question lessons appear in Appendix F.

Lesson Three was, on the other hand, collected and scored (although not entered into the gradebook). In order to complete this lesson, the students, working in pairs, coded a series of questions using either the code number (1-4) or the first letter of the question type (M - memory, R - relational, I - inferential, E - evaluative). On review of their coding, it became immediately apparent that identifying memory questions was not difficult with 93% of those questions identified as such. Students were somewhat less successful with recognizing the other question categories, correctly identifying 76% of the relational questions, 67% of the inferential and 75% of the evaluative questions. Since seventh graders have some difficulty with the concept of 'inference', it is no surprise that they have more trouble identifying inferential questions as well. It is interesting to note, furthermore, that both classes' (the high math ability and the mixed math ability) success was equivalent with identical coding for four of the five Memory questions, while the high math group was more accurate on six others, and the mixed ability group was more accurate on five others. Table 7 shows the average scores for each question and question category with both classes' results combined. All data henceforth will be presented in the same manner with both groups combined, as there were not consistent differences in terms of question coding or answer coding. The exception is that the mixed ability class's average test scores were lower.

Table 7
Question Lesson Three – Students' Coding of Sample Questions, (N=43-44)

% Correct Lesson 3 Question Coding								
Question/ Answer Code	Memory		Relational		Inferential		Evaluative	
	Ques.	%	Ques.	%	Ques.	%	Ques.	%
	2.	100%	5.	76%	3.	86%	1.	70%
	4.	72%	8.	89%	6.	50%	11.	68%
	7.	100%	9.	53%	12.	66%	14.	86%
	10.	95%	13	84%				
	15.	100%						
Average %		93%		76%		67%		75%

The students seemed to find question 11 to be the most problematic: 11. "What is the most important rule here at Seton?" Somehow they interpreted this to mean it was a simple, factual memory question instead of an evaluative one; when pressed, they realized that there is not a stated number one rule and that, in fact, this is not so straightforward a question as they had assumed. Another source of confusion was in instances of relational questions, such as: 9. "Why does ice melt?" Many students (almost 50%) coded this as a memory question because they could remember the answer; they had to learn how to code the question-type instead of the content.

Question Lesson Four required that students read a selection (included in Appendix F) and write questions about the selection, one per paragraph. The initial intent was for students to then code one another's questions; however, most students coded their questions as they wrote them. The majority of the seventh graders also attempted to write questions from all or most of the categories, evidence that they took the exercise seriously and were actively engaged in learning from it. There were, however, a few students whose questions suggest that they were more interested in asking questions

about the topic (the extinction of the dinosaurs) rather than asking questions according to the question categories.

Most questions asked were memory questions (53%, *N*=204 questions posed); the remainder of questions fell into the higher categories, such that 26% of questions posed were relational (*N*=54), 7% were inferential (*N*=14), and 12% evaluative (*N*=25). 68% (*N*= 108) of students' coding was correct. Memory questions were also the ones that students were most successful at coding properly (39%, N=158 questions coded). Of the 32% (*N*=50) of questions coded incorrectly, only seven were memory questions (4% of all question coding); 4% of relational questions were also miscoded, but there were far fewer relational questions asked. Most of the miscoded questions should have been coded inferential (*N*=158 or 13%) or evaluative (*N*=158 or 10%). This observation is not surprising as those are the most sophisticated types of questions; it also reinforces the observation made above for Lesson Three in which memory questions were the only ones that were coded with near unanimity and highest accuracy. These data are displayed in Table 8.

One possible difficulty with the coding scheme was that some students seemed to have trouble identifying memory questions, perhaps because they were focusing on the idea that they must remember the answer. Consequently, perhaps *memory* should be relabeled as *factual*, in order for students to focus on the factual nature of the question rather than whether or not they, personally, know the answer.

Table 8
Question Lesson Four – Students Coding of Their Own Questions, (N=158)

Question/Answer Code		
Question Posed	Total	% of Total Questions Posed
Unclear	2	1%
Memory	107	53%
Relational	54	26%
Inferential	14	7%
Evaluative	25	12%
Correctly Coded Questions	Total	% of Total
Memory	61	39%
Relational	24	15%
Inferential	7	4%
Evaluative	16	10%
Miscoded Questions	Total	% of Total
Memory Miscoded as Referential	7	4%
Referential Miscoded as Memory	4	2%
Referential Miscoded as Inferential	1	1%
Referential Miscoded as Evaluative	2	1%
Inferential Miscoded as Memory	11	7%
Inferential Miscoded as Referential	6	4%
Inferential Miscoded as Evaluative	3	2%
Evaluative – Ambiguous	1	1%
Evaluative Miscoded as Memory	7	4%
Evaluative Miscoded as Referential	5	3%
Evaluative Miscoded as Inferential	3	2%

Student Questions

The direct test of whether or not the students were able to integrate and apply the question treatment was to identify the kinds of questions that they asked, both orally and in writing. I expected to find that the coding of questions would show a trend toward higher level questioning when comparing questions from the pre- and post-treatment units. In fact, I found that the post-treatment questions did, indeed, include more higher level questions when students wrote the questions and when they asked questions orally, than the pre-treatment questions.

Students were asked to write questions on numerous occasions; this was done by means of an exit slip on which they were to indicate their muddiest point or point of greatest confusion. If, on the other hand, they felt so confident that they had no questions about current content, they were asked to think ahead and ask a question that related current content to how it might relate to other experiences the students had had, e.g., "How does (sic) the things we've been talking about relate to biomes?" These types of questions were collected three times from the pre-treatment electricity unit and three times from the post-treatment meteorology unit. This was done via quarter sheets of paper, distributed and collected at the end of a class. I used their slips either for re-teaching on the following day or for review prior to a summative assessment within a couple of days of collecting the slips. The students appreciated having their questions answered and, as noted below, many found the process to be helpful.

All written questions were collected and coded. Table 9 shows the distribution of questions coded for each set of exit slips as well as the lesson topic and the date they

were collected. While the majority of questions posed in all sets were relational, the percentage of relational over memory questions increased dramatically from the pre- to the post-treatment sessions. Overall, the average of pre-treatment electricity memory questions (46%, *N*=59) closely matched the relational ones (48%, *N*=61). Only 4% of the questions asked were higher level questions with a total of five inferential questions asked. Conversely, the post-treatment meteorology questions showed a disparity between memory and relational questions such that the memory questions comprised only 19% (*N*=25) of the total questions asked, while 67% (*N*=88) of questions posed were relational. Additionally, the sum and percentage of inferential questions doubled from pre- to post-treatment units with ten questions accounting for 8% of the total. There was even one evaluative question asked during the meteorology unit.

Table 9
Student Questions Collected Via Exit Slips

Exit Slip Questions – Topic, Date	Q/A Code						
	Ambiguous	Memory	Relational	Inferential	Evaluative	Sum	Total
Pre-treatment/ Electricity							
Static electricity, 12/8/11	2; 5%	17; 43%	19; 48%	2; 5%	0	40	
Ohm's Law, 12/19-20/11	1; 3%	17; 43%	18; 45%	3; 8%	0	39	
Current electricity, 1/17/12	0	25; 51%	24; 49%	0	0	49	
SUM	**3; 2%**	**59; 46%**	**61; 48%**	**5; 4%**	**0**		**128**
Post-treatment/ Meteorology							
Radiation lab , 2/24/12	6; 14%	4; 9%	32; 73%	2; 5%	0	44	
Heat transfer, 3/2/12	1; 2%	7; 16%	30; 67%	6; 13%	1; 2%	45	
Humidity, 3/12/12	0	14; 33%	26; 62%	2; 5%	0	42	
SUM	**7; 5%**	**25; 19%**	**88; 67%**	**10; 8%**	**1; 1%**		**131**

Figure 1 shows these data graphically. There is a clear trend displayed that shows that students asked higher level questions after receiving instruction in that metacognitive skill. It should be noted that some students did not form their queries into the form of questions, writing for example, "I am confused about resistance." Upon consideration, these were coded with the questions because the coding referenced the content rather than format. Note also that the incidence of statements submitted as questions declined over time, such that the number of exit slip "questions" turned in as statements decreased from

15 before the question lessons (*N*=3, 7, and 5, respectively) to only six following the treatment (*N*=0, 3, and 3, respectively).

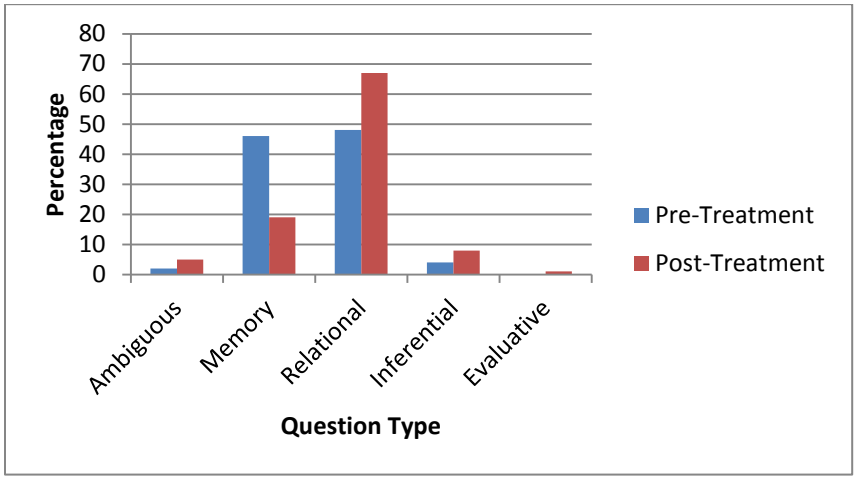


Figure 1. Student Questions Collected Via Exit Slips.

Classroom discussions were audio-recorded on four occasions, twice during the electricity unit and twice during the meteorology one. The duration of recording was about 20 minutes for each electricity session and 30 and 10 minutes, respectively, for each meteorology session. The number of questions collected was comparable across all sessions (*N*=30, 27, 30, and 28, respectively). The students participated eagerly in the discussions and also requested the right to choose their own pseudonyms; consequently, many of the pseudonyms are comical and not typically names that I would have chosen! All recordings were transcribed verbatim and then questions and answers were coded, both mine and theirs.

Several criteria were applied when identifying questions. Thus, the following behaviors did not constitute questions**:**

- Tag questions, e.g., Teacher: "So that makes sense, right?"

- Answers stated with interrogative prosody, e.g., Robbie: "Friction?" as an answer, and Teacher: "So that means of charging is…?"
- Repetitions, e.g., Teacher: "What is it touching?" … "What is touching the ground?" or: "What else?"
- Requests for repetition, e.g., Shawn: "What is it equal to?" as an answer to Teacher: "What is equal to the atomic number?"

Student questions were analyzed to reveal somewhat ambiguous results but a slight trend toward higher level questions and support of the study's objectives. Memory questions increased from pre- to post-treatment (from 35% of questions asked to 43%), and relational questions decreased (from 42% to 22%, respectively). This was not anticipated and does not support my claims. However, the percentage of inferential questions increased from 21% (*N*=12) to 31% (*N*=18); this is encouraging, especially because the final post-treatment recording session was also the shortest. Finally, there was only one evaluative question asked during the pre-treatment sessions and two asked during the post-treatment sessions. Figure 2 shows this information graphically, and Table 10 summarizes it.

Table 10
Coding for Student Questions Asked During Audio-Recorded Discussions

Class Discussion Questions – Topic	Q/A Code						
	Ambiguous	Memory	Relational	Inferential	Evaluative	Sum	Total
Pre-treatment/ Electricity							
Static electricity, 12/14/11 (about 20 minutes)	0	13; 43%	10; 33%	6; 20%	1; 3%	30	
Electromagnetism, 1/25/12 (about 20 minutes)	0	7; 26%	14; 52%	6; 22%	0	27	
Sum	**0**	**20; 35%**	**24; 42%**	**12; 21%**	**1; 2%**		**57**
Post-treatment/ Meteorology							
Heat transfer, 3/6/12 (about 30 minutes)	0	12; 40%	8; 27%	8; 27%	2; 7%	30	
Humidity, 3/13/12 (about 10 minutes)	0	13; 46%	5; 18%	10; 36%	0	28	
Sum	**0**	**25; 43%**	**13; 22%**	**18; 31%**	**2; 3%**		**58**

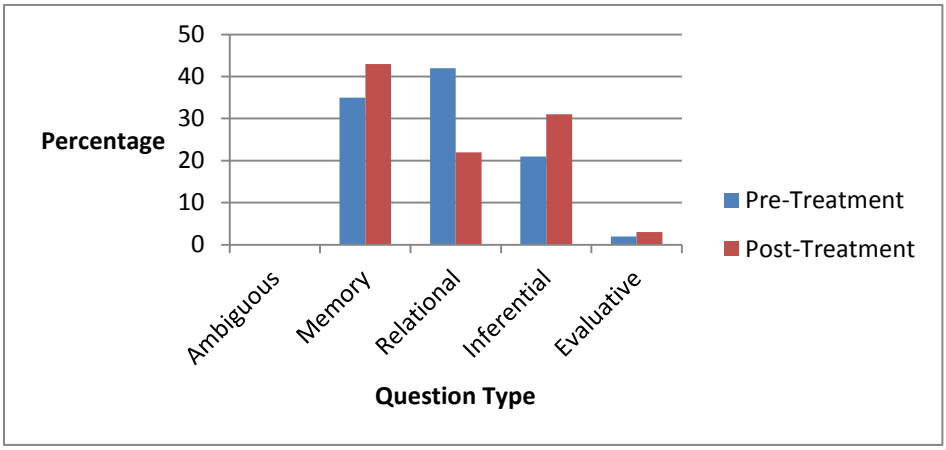


Figure 2. Student Questions Asked During Audio-Recorded Discussions.

Finally, students' oral questions, recorded during discussions were analyzed in terms of relevance; some questions clarified or extended topics. In the electricity discussions, 25 student questions spanning the two discussions served to elaborate

beyond the immediate scope of the discussion; 28 meteorology questions, spanning both discussions, served this purpose as well. Questions of this type included, Ryan: "If you send electricity through a coil of wires, will it make a like (sic) a magnetic field?" or Mitoshka: "So, the greenhouse effect, does that sometimes cause global warming?" These observations provide only very slight support for the study's objective; extending questions do increase from pre- to post-treatment but not in large quantity. Again, however, note that the shortest recording session showed the greatest number of clarification/extension questions (more than half (54%) of the questions asked), suggesting a positive trend. See Table 11 below.

Table 11
Student Oral Questions that Extend or Clarify

Class Discussion Questions – Topic	Total	Percent of total questions asked	Total (pre- vs. post-treatment questions)
Pre-treatment/Electricity			25
Static electricity, 12/14/11 (about 20 minutes)	14	47% (14/30)	
Electromagnetism, 1/25/12 (about 20 minutes)	11	41% (11/27)	
Post-treatment/Meteorology			28
Heat transfer, 3/6/12 (about 30 minutes)	13	43% (13/30)	
Humidity, 3/13/12 (about 10 minutes)	15	54% (15/28)	

Student Responses/Answers

The second objective of the study was to determine whether the students would spontaneously apply the lessons in questioning strategies to the answering of questions.

My hope was that I would find higher level responses to questions posed during the post-treatment meteorology lessons than during the pre-treatment electricity lessons. In fact, students gave higher level responses to post-treatment questions than pre-treatment questions when writing the answers and, to a more limited extent, when answering questions orally.

In order to make these comparisons, student answers were also coded using the question/answer rubric; answers, like questions, were both written and oral. Student written responses were solicited via half-sheet class warm-ups, as assignment summaries, and as a creative writing assignment. The half-sheet question prompts appear in Appendix C and I for the electricity and meteorology units, respectively. Additionally, for each unit, there was a prompt that was more creative in nature.

An analysis of student answers indicates that answer code very often correlated with question code such that the type of question asked usually elicits a matching answer; for example, ordinarily, asking a memory question elicits a memory answer. However, as shown in Table 12 and Figure 3, there are two patterns that indicate a trend toward higher level written answers that parallels the trend toward higher level questioning identified earlier. Specifically, 24% (N=28) of pre-treatment responses were coded in the memory category, while only 1% of post-treatment responses received that minimal coding. Furthermore, only 7% of pre-treatment responses were higher level responses than the question asked; all 7% (N=8) were evaluative responses to relational or inferential questions. On the other hand, 38% of meteorology responses to the relational question were higher level responses; 15 were inferential and one was evaluative.

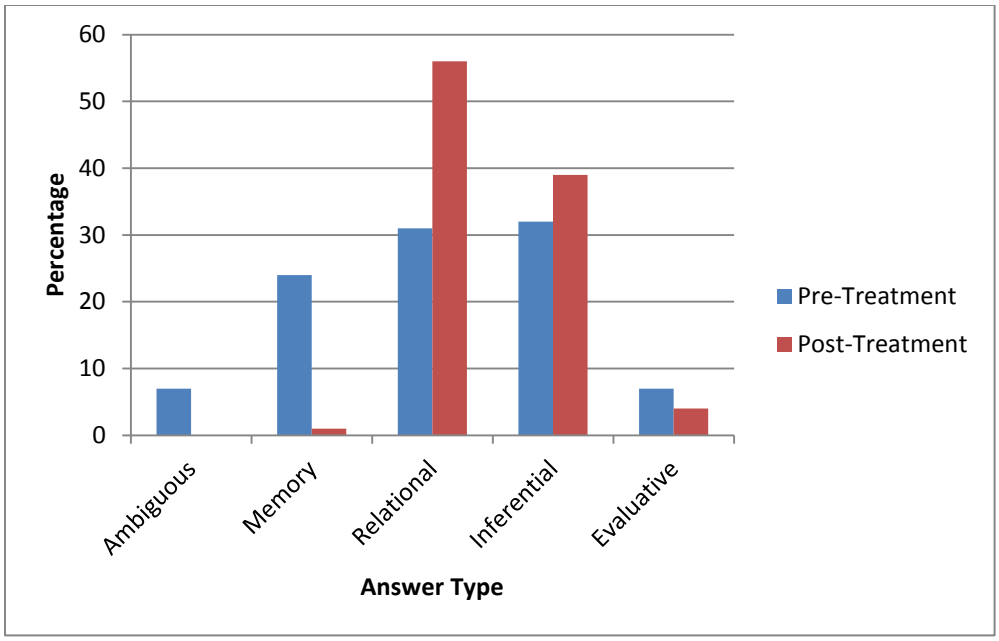


Figure 3. Student Written Responses to Reflective Questions.

Table 12
Student Written Responses to Reflective Questions

Written Reflections/Answers – Topic	Q/A Code						
	Ambiguous	Memory	Relational	Inferential	Evaluative	Sum	Total
Pre-treatment/ Electricity							
Static electricity (Inferential), 12/16/11	0	0	0	38; 95%	2; 5%	40	
Amperage vs. Voltage(Relational), 1/6/12	3; 7%	24; 59%	13; 32%	0	1; 2%	41	
Voltage (Relational), 1/17/12	5; 13%	4; 11%	24; 63%	0	5; 13%	38	
Sum	**8; 7%**	**28; 24%**	**37; 31%**	**38; 32%**	**8; 7%**		**119**
Post-treatment/ Meteorology							
Radiation lab (Open) , 2/24/12	0	1; 2%	36; 86%	4; 10%	1; 2%	42	
Greenhouse effect (Relational), 3/7/12	0	0	26; 62%	15; 36%	1; 2%	42	
Water molecule (Inferential), 3/9/12	0	0	5; 14%	27; 77%	3; 9%	35	
Sum	**0**	**1; 1%**	**67; 56%**	**46; 39%**	**5; 4%**		**119**

Some examples of answers that were coded higher than the initial question include the following. In describing how voltage is like Niagara Falls, Fernanda said: "Voltage can be compared to Niagara Falls because the electrons flow through the wires like the water flows down a waterfall. Anything blocking the water flow of a waterfall is like resistance against the flow of electrons." Emma explained why the greenhouse effect is necessary: "It is necessary to maintain life on Earth because without trapping heat, the world would be cold."

Furthermore, a perusal of Table 13 will show that in some instances, responses showed higher level content as well as question type. That is, there were instances when students used an answer to extend a topic, rather than just answering or supporting the question posed; this increased in the post-treatment discussions. These data appear to support the objective, albeit weakly, in that there was a little more extension of basic concepts in post-treatment responses. In addition, fewer wrong answers were made in post-treatment responses. Examples of responses that extend concepts beyond the question asked are included here. David described how voltage is like Niagara Falls: "Electricity in Water Words: Volts = amount of water at the top of Niagara Falls; volts or water you start out with. Current = how much water is getting through; current or falling water. Resistance = what is holding up the water from flowing, like a narrow stream or a big rock in the way;" a small illustration accompanies each term. Norris explained why the greenhouse effect is necessary to maintain life on Earth: "So that plants grow, and if plants grow then we can get O_2."

Table 13
Comparison of Student Written Answers That Extend Concepts as Well as Those That Were Wrong

Written Reflective Answers		
	Extended beyond answer sought	Wrong
PRE-TREATMENT		
Electricity – Static electricity (Inferential)	2	11
Electricity – Amperage vs. voltage (explain illustration) (Relational)	1	3
Electricity – Compare voltage to Niagara Falls (Relational)	0	24
POST-TREATMENT		
Meteorology – What I learned from this lab (Open)	n/a	0
Meteorology – Greenhouse effect (Relational)	16	2
Meteorology – Particle motion of water vapor (Inferential)	3	4

Finally, students' oral answers to teacher questions in the recorded discussions were also analyzed. As was mentioned above, response types usually match the type of question asked and are thus not very illustrative. These data do not support the objectives of the study.

Summative Assessments

Another objective of the study was to determine whether the question intervention contributed to the improvement of summative assessment scores. Thus, comparisons

were made of the current and previous years' meteorology summative assessments as well as a comparison between the pre- and post-treatment summative assessments for the current 2012 academic year. The intervention appears to have had a positive effect on student learning.

Some test questions (three multiple choice questions and a short answer graph-interpretation question) were identical on the 2011 and 2012 assessments; see Appendix K. An analysis of the responses to these questions shows that, with one exception, the scores from one year to the next were virtually identical. The exception is the one that most directly addressed the misconception that I identified last year when the students seemed unable to grasp the concept that water vapor/gas condenses to liquid water to form clouds. In the case of that multiple choice question, student performance was much more accurate in 2012 than in 2011. In 2012, 67% (N=43) of students selected the response indicating that clouds are made of liquid not gas while in the previous year only 15% (N=40) succeeded in answering this question correctly. Additionally, the overall scores on the tests were higher in 2012 than in 2011, with the average score improving from 83%, a C+, in 2011 to 88%, a B, in 2012. Table 14 displays these data.

Table 14
Meteorology Summative Assessment Scores, 2011 and 2012 (Post-treatment)

Test Question – Full Credit Awarded	2011 Score	2012 Score
MC 1 – contents of a cloud	6/40, 15%	29/43, 67%
MC 2 – density of water	26/40, 65%	27/43, 63%
MC 3 – thermal energy and phase change	40/40, 100%	43/43, 100%
Short Answer – graph interpretation	34/40, 85%	35/42, 83%
Overall Test Score	83%, C+	88%, B

Another aspect of the 2012 summative assessment was that I included a restatement of the misconception probe that I used in class prior to introducing the water cycle. The probe stated: "On a hot, summer day, your glass of Coke develops water droplets on the outside. This water … a) came from inside the glass; b) came from a cloud; c) was always there; we just didn't notice it before." When it was used as an introduction in class 81% (*N*=43) of students answered correctly; when it was given as a test question 84% (*N*=43) of students gave the correct response. Thus, there was only the very slightest support for the objective, as the scores were nearly identical and were fairly high to begin with. Unfortunately, this also indicates that for a few students the misconception still existed, and further re-teaching was necessary.

A contrast of the extended responses from the 2012 pre- and post-treatment summative assessments (see Appendix J) did not show evidence of higher level responses. In fact, the pre-treatment electricity responses received slightly higher codes and scores than the post-treatment meteorology ones.

Student Attitude, Self-Confidence, and Autonomy

The final research question addressed the possible relationship between the metacognitive skill introduced and students' attitudes toward science. It was anticipated that students would be more confident once they had learned a skill (developing higher level questions) that they could apply to support their learning. While there was little change form pre- to post-treatment for the majority of survey questions, there was, nevertheless, a measurable shift in autonomy and increase in confidence. Furthermore, there was evidence that they had some metacognitive awareness and that they found value in the question intervention.

The students were surveyed twice, a subset was interviewed, and students reflected on effective tools to support their learning. Students completed a Likert-type survey consisting of 20 questions (five each addressing attitude, metacognitive awareness, confidence, and autonomy) at two times, once at the conclusion of the electricity unit and prior to the question intervention and once in conjunction with the meteorology summative assessment. Responses ranged from 1-4 where 1indicates strong disagreement, and 4 indicates strong agreement. A copy of the survey can be found in Appendix D. Additionally, six students were interviewed at both of those times; these are the same students who were interviewed about the question lessons. Finally, the 2011 and 2012 meteorology tests concluded with a reflection. (I usually do a reflection of some type at the end of summative assessments, so the students are familiar with the format.) In this case, the reflections for 2011 and 2012 were quite similar and asked students to check the activities that they felt were most effective in helping them to learn.

Students showed a fairly positive attitude toward science in statements numbered 2, 4, 8, 10, and 16 where the mode always indicates agreement; however, there was little change from one survey to the next. Likewise, students showed metacognitive awareness in statements numbered 6, 12, 13, 18, 20 (indicating that they think about science and how to conduct labs, they ask thoughtful questions, and they try to learn from their mistakes or misunderstandings); again the modes are consistently positive but there is little change from one survey to the next. Student autonomy was addressed by statements numbered 9, 14, 15, and 19. These indicate a shift in autonomy from a preference to studying with parents to a preference for working with peers. While probably unrelated to the focus of this study, the shift is in keeping with the socialization so typical of this age group! Thus, in general, these students appear to see the value both in science and in taking responsibility for their learning.

Student confidence (addressed by statements numbered 1, 5, 7, 11, and 17) on the other hand, showed one significant change from the pre- to the post-treatment survey. Specifically, the fifth statement, “This unit was rather easy for me to learn,” showed a shift prior to the electricity final assessment from a mean of 2.2 where the mode was 1, indicating disagreement, to a mean of 2.6 where the mode was 3, indicating agreement, prior to the electricity summative assessment. It appears that the lessons in a metacognitive skill, questioning strategies, accomplished their intended consequence with a positive impact on student confidence. Table 15 summarizes the survey results with the questions grouped according to category. P-values were calculated using 2-tailed paired t-tests where the degree of freedom was n-2. For question five, the difference between

the pre-treatment measure of confidence (M=2.2, SD=1.1) and the post-treatment measure (M=2.7, SD=.9) was statistically significant, p=0.02.

This conclusion is supported by the fact that the interviewees also responded more positively during the final interview. Before the electricity summative assessment, three said that, yes, they felt that they "understand ideas well when it is time to take a test," while the others said, Sally: "Usually;" Mr. S.F.: "A little bit;" and "Moira: "Not all the time. I'm nervous for this test." Prior to the meteorology summative assessment, when asked whether they understand ideas when it is time to take a test, four said, "Yes;" Sally said, "Most of the time;" and Moira said: "Sometimes. This chapter is easy kind of 'cause (sic) I get it. Atoms were difficult for me."

Table 15
Confidence Survey Results, (N=43)

Category	Question #	January Mean; Mode	March Mean; Mode	p-value
Attitude		2.7	2.72	.82
	2	3.2; 3	3.2; 4	1.0
	4	2.3; 3	2.4; 2	.54
	8	2.9; 4	2.8; 3	.66
	10	3.3; 4	3.1; 4	.26
	16	1.8; 1	2.1; 1	.31
Metacognition		2.88	2.86	.799
	6	2.9; 3	3.0; 3	.61
	12	3.5; 4	3.2; 3	**.05**
	13	3.0; 3	3.0; 3	.75
	18	3.1; 3	3.1; 3	1.0
	20	1.9; 1	2.0; 1	.78
Autonomy		2.46	2.38	.554
	3	2.4; 1	2.0; 1	**.05**
	9	2.3; 1	2.5; 1	.41
	14	2.0; 2	1.9; 2	.51
	15	2.4; 2	2.6; 3	.18
	19	3.2; 4	2.9; 4	.3
Confidence		2.74	2.8	.552
	1	2.6; 2	2.7; 2	.71
	5	2.2; 1	2.6; 3	**.02**
	7	2.4; 2	2.3; 2	.91
	11	3.2; 4	3.1; 4	.7
	17	3.3; 4	3.3; 4	.9

As a means of assessing whether students saw value in the question strategy intervention, they were asked to complete a simple reflection addressing learning aids. At the end of each of the meteorology summative assessments, in 2011 and 2012, a list of options was included with instructions for students to check any classroom activities that they deemed helpful to their learning. Since students could check more than one, and they were not asked to rank their preferences, a large number of responses was collected; all are summarized in Table 16. The reflection checklists themselves can be found in Appendix L.

Table 16
2011 and 2012 Summative Assessment Student Reflections

	2011 N=40	2012 N=43
taking notes	1.80%	1A. 86%
doing labs	2A. 50%	1B. 86%
math practice	2B. 50%	**6. 47%**
reading textbook	3. 35%	2. 74%
practice worksheets	4. 33%	n/a
asking questions/muddiest points	n/a	3. 72%
interpreting diagrams	n/a	4. 65%
reflections/answers (half-sheets)	n/a	5A. 49%
doing section reviews	5. 28%	5B. 49%
		6. see above
graphing observations	n/a	7. 44%
watching DVDs	6. 15%	8. 28%
referring to Dr. S's webpage	n/a	9. 12%

There are two important observations to make regarding these data with respect to the confidence and metacognitive awareness of these students. The first refers to the

range of learning methods that the 2012 seventh graders acknowledge as helpful. Specifically, eight of the learning aids were identified as useful by approximately 50% or more of the students. While probably unrelated to the intervention introduced for this study, these data indicate, again, that the majority of this group takes their responsibility for learning seriously. Furthermore, 72% of students acknowledged that asking questions was beneficial, and 49% checked the answering of questions as beneficial as well. Thus, it appears that the students saw the value in asking and answering questions, supporting the contention that the students applied the question intervention in order to ask higher level questions and provide higher level answers.

Further supporting the idea that students were receptive to using the question lessons to help themselves learn was Moira's response to the interview question, "Do you think the question lessons will be helpful to you?" She said, "Good questions get good answers, and then you can do better on tests." Zander felt that the "coding is not as helpful, but asking good questions, yeah, I think that's very, very important. Then you know how to word your answers and how to word questions." He went on to explain that when Shawn asked how to spell DNA (some weeks before), and she was laughed at, "What she really wanted to know was how to spell deoxyribonucleic acid, but she didn't ask it right." It is interesting to me that it was the lower-achieving students who were quickest to see the uses of this new strategy in gathering and commanding information. On the other hand, Anna, a very high-achieving student, saw less use in question strategies, acknowledging grudgingly that it could help give "different ways to understand what they're asking is the best answer." She went on to ask a very insightful question, however, when she said, "When I was little I asked more of the first type; your

questions get more complicated [as you get older]. Why is that?" We had a nice conversation after that about cognitive development.

INTERPRETATION AND CONCLUSION

A constructivist approach to teaching and learning requires that a teacher helps students develop the ability to identify and assess the state of their own conceptions. Thus, the classroom should not be a place for simply imparting information but also one in which students are actively engaged in interacting with that information. In the case of this particular study, the students participated in the pre- and post-treatment units through labs, written (exit slip) questions, written reflective responses, extended oral discussion, written homework answering section review questions, and calculations using Ohm's Law or relative humidity percentages. The intervention presented between the two units was designed to help students use questions effectively to assess their own knowledge and seek to redress gaps.

Overall, students developed their means of self-evaluation, becoming more adept at asking substantial questions as shown by the increase in higher level questions. Furthermore, they also increasingly used their questions, both written and oral, to clarify and extend concepts, supporting the idea of knowledge-development via concept construction. Finally, the direct focus on questioning strategies helped students to construct their questions syntactically as questions.

There was no explicit connection between question strategies and the development of answers presented to the students at any point during the intervention. It was, however, interesting and encouraging that both Moira and Zander made that

connection when they were interviewed. For the purposes of the research, I wanted to see whether students would apply the question lessons to answers. Written responses did, in fact, show a shift to higher level questions, indicating that the students had transferred the question lessons to their answering as well. This occurred despite the fact that, with both written and oral responses, the majority of answer codes matched the question code, an outcome that should perhaps have been anticipated. On the other hand, the final audio-recording, albeit the shortest one, included the most high-level answers, an encouraging trend. It is unfortunate that the extended response scores for the pre- and post-treatment summative assessments did not show a positive trend; however, a long term comparison with well-controlled question content and structure is probably necessary to identify potential trends in this area.

Finally, it was gratifying to note that students had a positive attitude toward science, responsibility for learning, and had a measure of confidence as well. The most significant development between the first and second survey was the increase in confidence expressed just prior to the meteorology summative assessment in contrast with the confidence shown prior to the electricity one, according to item 5: "This unit was rather easy for me to learn." This support for the questioning intervention as a useful metacognitive strategy is supported by the fact that 72% of the seventh graders (N=43) cited 'muddiest point questions/exit slips' as an effective means of helping them learn, as expressed by their test reflections. Moreover, the majority of students also answered in the affirmative item 18: "I ask thoughtful questions about science," and in the negative item 20: "When I don't understand an idea, I just move on anyway." All these responses

are signals that these students have some metacognitive awareness and have acknowledged the value in asking effective questions.

Certain complications with the coding scheme were identified during the question intervention. One of those was that students tended, in the beginning, to confuse the content with the nature of the question. For example, 48% of students (*N*=44) coded "Why does ice melt?" as a memory question instead of a relational one during Lesson Three. Upon further discussion, it seems that they did so because they remembered the answer. The labels for each question category were originally developed in conjunction with the literature reviewed earlier in this paper. However, instances of confusion like this have convinced me that memory questions should be relabeled as factual next year, so that the categories are more transparent to the students actually learning the strategies. Far more problematic is the evaluative category which proved to be almost useless for the duration of this project. In a middle school science class, there is really very little opportunity for students to be in a position in which they might be able to adequately evaluate a concept; they simply do not yet have enough information on which to base an opinion or a persuasive argument. A far better label for this type of question and answer would have been evidential. Questions and answers of this type would be those that require evidence to support them; in fact, Ciardiello's (1998) evaluative category requires judgment and justification of choices, an idea that will be developed next year. Moreover, during the interviews following the question lessons, Moira answered the question: "What is most confusing to you?" by saying, "Just the E really because when you think of an 'e,' you think of 'evaluate,' but this says, 'What's your opinion?'" Examples of explicitly evidential questions might be: "What evidence is there to suggest

that a hurricane will weaken when it moves over a continent?" or "What factors cause a sea breeze to blow during the day?" In sum, category one will change from memory to factual, and category four will change from evaluative to evidential.

VALUE

The goal of this project was to help students develop metacognitive skills, increasing their ability to self-evaluate and construct accurate scientific knowledge conceptions. Despite covering a relatively short period of time, just two months, the students showed evidence of applying the question strategies lessons, thus, developing an effective means of assessing their own understanding. The intervention supported the educational goals identified by Lin (2001), providing students with frequent opportunities to assess and articulate their own learning. There is slight evidence that this helped them learn content necessary for being successful at summative assessments. In addition, Clark, Chow-Hoy, Herter, and Moss's (2001) contention that students become more engaged when they "can actually influence the course of their work" (p. 235) seems justified given students' increased confidence and positive response to writing exit slip questions. Their test reflections indicate that many of them liked being able to ask written questions, knowing that their queries would be answered and clarified. Thus, I will continue to use the question lessons in future years with seventh and eighth graders, albeit with the changes to categories one and four mentioned above. Moreover, I will introduce the question lessons earlier in the year, allowing students to develop the strategies more effectively.

Furthermore, having seen already that the students began to extend the question strategies to their answers, I will explicitly make that connection for them in the future, linking the asking of effective questions to the construction of more thorough responses. Already, 49% of students (*N*=43), indicated on their test reflection that the half-sheet written responses to question prompts were helpful to them in learning. The prompts highlight for students concepts that are important, and they give students an opportunity to articulate their thoughts. They also serve as an important formative assessment tool for the teacher, indicating the extent to which students' conceptions match the intended targets and also indicating misconceptions. Using prompted reflections of this kind with seventh and eighth grade students, thus, will encourage continuous development of knowledge constructs. Hopefully, over time they will also contribute to improvement in extended response scores on summative assessments as well.

For the current seventh graders, upon entering eighth grade I will integrate these lessons with a set of lessons and activities developed by the National Institutes of Health ('Inquiring Minds' Doing Science: The Process of Scientific Inquiry) that develop the idea that scientific questions are testable. Having had the current seventh grade experience of focusing on questioning strategies, next year they will have a better framework in which to insert and re-construct the relevance of asking questions than the current eighth graders who did not have the benefit of lessons on basic questioning strategies.

This experience has shown me, as mentioned above, that I ask more effective questions when I prepare them in advance. The transcription of audio-recordings revealed a pattern in which I activate and evaluate students' prior knowledge via memory

questions and then move on to relational ones, using ‘why’ and ‘how’ questions to relate prior knowledge to new information and explore the way in which those ideas interact. Finally, I use inferential questions (and evidential ones although my current coding scheme was ineffective in describing those) to construct new, more sophisticated conceptions. Seeing this pattern in the transcripts leads me to believe that the explicit teaching of question strategies to students reinforces my own teaching method. Thus, the students will have (and have had in the past) effective modeling of the strategies I am seeking to bring into their conscious awareness. Both the question strategies introduced herein and my modeling of concept construction encourage students to develop learning strategies and monitor the state of their learning and knowledge. Future research will focus on the metacognitive function of students’ questions, identifying them as serving the purpose of monitoring, evaluating, or regulating thoughts.

The process of action research has been highly beneficial to me as a means of identifying and evaluating the techniques I use in the classroom. Thus, just as the example above shows, further research will identify effective strategies as well as strategies that fall short of improving student learning. Moreover, identifying and distinguishing cognitive and metacognitive skills is valuable in directing the teacher-student partnership to manage learning. The learning community is most successful when all parties understand the goals as well as the means of reaching and evaluating those goals.

The process of collecting and analyzing student data, pertaining to a particular skill, provides the researcher with specific information as to student achievement. Rather than relying on generalizations, e.g., “The summative assessment scores improved over

last year," action research data allows for a detailed comparison, showing exactly what changes occurred for each student: improvement, decline, or neither. Furthermore, outliers can be identified in order to provide intervention where necessary to benefit the students who have failed to achieve; no students can fall through the cracks if careful, comparative analysis has been completed. Any professional development that includes strategies for assessing the outcome, is inherently going to more successful than training without a means of determining its benefit to students.

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APPENDICES

APPENDIX A

QUESTION AND ANSWER CODING RUBRICS

Appendix A

Question and Answer Coding Rubrics

Question and Answer Coding Matrix

Ciardiello (1998) Question types	Kuhn & Dean (2004) Epistemological Levels	Question Rubric	Answer Rubric
		0 – Ambiguous	0 – Ambiguous
Memory	Absolutist	1A – Logistical	
		1B – Factual	1 - Factual
Convergent	Relativist	2 – Relational	2 – Relational
Divergent		3 – Inferential	3 – Inferential
Evaluative	Evaluativist	4 – Evaluative	4 – Evaluative

APPENDIX B

ELECTRICITY UNIT DISCUSSION QUESTIONS

Appendix B

Electricity Unit Discussion Questions Asked by Teacher

Pre-written questions are indicated with an asterisk*.

Other questions occurred spontaneously.

Static Electricity:

What does subatomic mean? (M)

*What are the subatomic particles? (M)

Where do we find each subatomic particle? (M)

*What does the atomic number represent? (M)

*What are the charges on the subatomic particles? (M)

What is equal to the atomic number? (M)

*Why do positive and negative charges need to be balanced? (R)

If an atom does not have an equal number of protons and electrons, how do you describe what you have? What is it called? (M)

How could an ion become charged? ($)

If a material loses electrons, what is the charge on the material? (I)

How might we lose electrons from a material? (R)

*What are some examples of static electricity? (R)

So what would we call that means of charging? (M)

If things rub against each other by friction, what happens to the electrons? (I)

Where did those electrons go? (I)

*Why do the electrons move? Why not the protons? (I)

In other words, was the plastic wrap positively or negatively charged? Could you tell by looking at it? (R)

What kinds of things did the charged plastic wrap pick up? (M)

So what method of charging charged the salt? Or the paperclip? Or the foil? (R)

What relationship do materials need to have in order for conduction to take place? (M)

*Compare and contrast methods of charging an object, friction, conduction and induction. How are they the same? How are they different? (R)

What is a conductor? (M)

What kinds of materials did you find serve as conductors? (M)

How did those electrons get from the battery, to the light bulb, through the paperclip? (R)

What are the materials that do not allow electrons to move freely? (M)

*Why does charge move in a conductor? (R)

Static electricity is called that because charge builds up, and then what happens to the charge? (R)

What is another means of transferring charge? (M)

What kinds of things were attracted to the plastic wrap? (M)

What is the most dramatic, huge example of static electricity you can think of? (M)

How are static electricity and lightning similar? (R)

*What would happen if lightning struck an insulator? (I)

*Have you ever heard of a lightning rod? (M)

*Where is the charge sent when it strikes a lightning rod? (I)

<u>Electromagnetism</u>:

What is a magnet? (M)

What is a characteristic of it that makes it have magnetic pull? (M)

What happens if you have two magnets with the same charge, and you try to put them together; what do they do? (M)

What if you put two ends together with the opposite charges? (M)

If there are a bunch of electrons on one side, what charge does that side have? (I)

So, the side that does not have all the electrons crowded around it, then would have what charge? (I)

*How can you compare and contrast electricity and magnetism? (R)

And how is a magnet different in terms of those electrons? (R)

*How does a piece of iron become charged? (R)

What happens when the iron cools and hardens? (I)

*If you have a magnet, how can it affect an electric current? (I)

*If you have an electric current, how can it affect a magnet? (I)

Faraday had an electric current, and he caused a magnet in a compass to move. Why would that have happened? (R)

*Why would a magnet move if there's a current in the space around it? (R)

What happens when you have electric current electrons near here? (I)

*If I have an electric wire, and I have a magnet turn towards it, what's it gonna do to electrons here? (I)

The electrons are elected and repelled over and over again. What would we call that movement of electrons? (R)

What does it mean to alternate? (M)

If an electric current can generate magnetism, then what is the flipside of electromagnetism? What else happens? (I)

What causes a turbine to turn? (I)

APPENDIX C

ELECTRICITY UNIT WRITTEN QUESTION PROMPTS

Appendix C

Electricity Unit Written Question Prompts

If you are dusting furniture in your house (rubbing it with a cloth), what might happen to electrons in your furniture? If the cloth becomes charged, what will happen next? (I)

How does your diagram (comparison and contrast of amperage and voltage) show the difference between current and voltage? (R)

How can voltage be compared to Niagara Falls? (R)

APPENDIX D

STUDENT CONFIDENCE SURVEY

Appendix D

Student Confidence Survey

Science Class Survey

To what extent do you agree with the following statements about the science that you have had at school? (Give your answer with a check for each line. If you do not understand, leave the line blank. Your participation is voluntary; you do not have to complete the survey.)

I am a boy ☐ I am a girl ☐

	Disagree			*Agree*	
1. School science is a difficult subject.	☐	☐	☐	☐	**C**
2. School science is interesting.	☐	☐	☐	☐	**A**
3. My parents usually help me with science homework and when studying for tests.	☐	☐	☐	☐	**Y**
4. I like school science better than most other subjects.	☐	☐	☐	☐	**A**
5. This unit was rather easy for me to learn.	☐	☐	☐	☐	**C**
6. When doing labs, I read directions and plan ahead.	☐	☐	☐	☐	**M**
7. I find it difficult to figure out science ideas.	☐	☐	☐	☐	**C**
8. The things that I learn in science at school will be helpful in my everyday life.	☐	☐	☐	☐	**A**
9. I prefer to study science alone.	☐	☐	☐	☐	**Y**
10. I think that the science learned at school will improve my career chances.	☐	☐	☐	☐	**A**
11. I was confident when I took the last science test.	☐	☐	☐	☐	**C**
12. I try to understand mistakes when I make them.	☐	☐	☐	☐	**M**
13. I sometimes take the time to think about what I am learning.	☐	☐	☐	☐	**M**
14. I rely on lab or table partners to explain things to me.	☐	☐	☐	☐	**Y**
15. I can understand what we are learning in science without someone helping me.	☐	☐	☐	☐	**Y**
16. I would like to become a scientist.	☐	☐	☐	☐	**A**
17. When I work hard I can figure out science concepts.	☐	☐	☐	☐	**C**
18. I ask thoughtful questions about science.	☐	☐	☐	☐	**M**
19. I learn science better when I can work with someone else.	☐	☐	☐	☐	**Y**
20. When I don't understand an idea, I just move on anyway.	☐	☐	☐	☐	**M**

Question Categories are indicated by the following codes:

Attitude – A Confidence – C

Autonomy – Y Metacognition - M

Codes will not appear on the Survey Monkey version of the survey.

(adapted from ROSE Survey, 2010)

APPENDIX E

STUDENT INTERVIEW QUESTIONS – ATTITUDE

Appendix E

Student Interview Questions – Attitude

1. Do you think science is difficult or not? Why do you think that?
2. Do you think science is interesting? Do you like it?
3. How do you study science? Do you study alone, or do your parents help you?
4. Do you go over your mistakes when you make them?
5. What is your approach to doing a lab? Do you usually plan what you are going to do or do you tend to just "wing it?"
6. Do you feel like you understand ideas well when it is time to take a test?

APPENDIX F

QUESTION LESSONS

Appendix F

Question Lessons

Lesson 1

Students will be introduced to question types, cognitive operations, and typical signal words via the table included here. They will then be asked to read sample questions and then generate questions of their own for each category. Note that the coding scheme will not be discussed with them until Lesson 3 (Ciardiello, 1998).

Question Type	**Cognitive Operations with Signal Words**	**Question Code**
		0- unclear
Memory	Naming, defining, identifying, designating; yes/no responses Signal words: *who?, what?, where?, when?*	1A – Logistical (how to do something) 1B - Factual
Relational	Explaining, stating relationships, comparing & contrasting Signal words: *why?, how?, in what ways?*	2 - Relational
Inferential	Predicting, hypothesizing, inferring, reconstructing Signal words: *imagine, suppose, predict; if …then, How might?, What are some possible consequences?*	3 - Inferential
Evaluative	Valuing, judging, defending, justifying choices Signal words: *defend, judge, justify, What do you think? What is your opinion?*	4 - Evaluative

Question Types Name: _____ Date: _____

Memory Questions

What is a synonym for theory?

Who was Georg Ohm?

Do all atoms have protons and electrons?

1.

2.

Relational Thinking Questions

Why does the number of electrons in an atom match the number of protons?

How are chemical properties of matter identified?

In what ways are physical changes similar to chemical changes?

1.

2.

Inferential Questions

What do you think would happen if a category 5 hurricane struck Haiti?

How might iron react if it is left out in the rain for a long time?

What are some possible consequences of introducing invasive species to an ecosystem?

1.

2.

Evaluative Questions

What do you think about killing mosquitoes with DDT to control malaria?

Why would you choose to live in a big city instead of Hudson?

How important do you think it is to protect the environment?

1.

2.

Lesson 2

The following questions will be randomized and handed out on paper strips. Students will post them on the board in the proper question-type column.

What is the meaning of the word isotope?

What are the names of the subatomic particles?

How many stages are there in the water cycle?

Do all students like to study electricity?

Are all non-native/foreign species invasive?

Which organisms have nuclei in their cells?

Which river is dirtier, the Ohio or the Cuyahoga?

Why do electrons move toward protons?

What happens when oceanic and continental crust meet?

Why does a solid melt when thermal energy is introduced?

In what ways are elements and compounds different?

How do electrons move in static and current electricity?

If we were to remove all the Japanese knotweed from the park, what would happen?

How might park rangers reclaim land that has been used as a dump?

What predictions can you make about building a base on the moon?

How might life be different if all people had enough to eat?

What are some possible consequences of using energy-efficient home appliances?

What would happen if we were to stomach acid with milk?

How do you feel about nuclear energy?

What do you think about the water company charging more so they can update sewers?

Why would someone prefer to study science instead of social studies?

How do you feel about tightening up our dress code, so no one can wear jewelry?

Why would citizens vote to protect more park land?

Why should all people in northeast Ohio root only for Cleveland teams?

Lesson 3

The following set of questions will be used by students to practice coding for depth and complexity, using the data table given to them in Lesson 1.

Question Coding Name: _____ Date: _____

1. Why would you prefer to live in Hawaii? _____
2. What is the name of the positive subatomic particle? _____
3. How would life be different if Faraday had not learned to use electricity? _____
4. Where should we write the code for each question? _____
5. How is potential energy converted into kinetic energy? _____
6. What do you think would happen if Lake Erie was so polluted that all the fish died? _____
7. What is kinetic energy? _____
8. How is electromagnetic energy different from thermal energy? _____
9. Why does ice melt? _____
10. What is the basic metric unit of mass? _____
11. What is the most important rule at Seton? _____
12. What are some possible consequences of tasting lab materials? _____
13. How is current related to resistance? _____
14. What do you think about having science homework every night? _____
15. What is the first step in the scientific method? _____

Lesson 4

In pairs, students will read the following selection and write questions for each paragraph. They will then exchange questions and code them for complexity, using the rubric included in lesson 1 (Wright, 2005).

THE STORY—PART 2

Scientific Sleuthing

One of the great puzzles in history is why the dinosaurs became extinct. Before exploring the theories about this extinction, consider first the history of Earth. The sweep of geologic time is divided and subdivided into distinct units, just as we carve up the time today into days, weeks, months, years, decades, and centuries.

Dinosaurs appear to have emerged during the Triassic period more than 200 million years ago. Following the Triassic period is the Jurassic period, which lasted about 45 million years. As movie director Stephen Spielberg captured in his film *Jurassic Park,* this was the time when dinosaurs dominated Earth. After the Jurassic period came the Cretaceous period. It ended about 65 million years ago. It was at the end of this stretch of time that dinosaurs became extinct. But why? This is the great puzzle.

Time has erased most evidence for the cause of the extinction. Dinosaurs may have died a slow death, their numbers dwindling gradually over thousands of years, or something catastrophic could have killed them all in a day or two. All we know is that the fossil record for dinosaurs dramatically and abruptly ends.

For many years, scientists have wondered what could have snuffed out the dinosaurs. One theory is that the climate changed enough to kill them; another theory blames a plague or disease. Some scientists have speculated that plant life was altered somehow, causing dietary problems in plant-eating dinosaurs and eventually leading to the extinction of the meat-eaters. An exploding star (a supernova) has also been posed as reasons for the extinction. Lethal doses of radiation cascading to Earth from such a failed star might cause mass extinctions by triggering climate changes and making Earth unsuitable for life.

Although each of these ideas has merits, each also has weaknesses. One of the more provocative theories today points to another possibility—perhaps the dinosaurs died in a single, massive, and catastrophic event 65 million years ago: perhaps a 6-mile-wide asteroid hit Earth!

STUDENT VOICES



I was in Nags Head, North Carolina, last August during the meteor shower. My friend and I were on the beach looking at the stars, when all of a sudden people behind us yelled, "Look at that!" I turned in time to see a meteor skipping across the sky. It appeared to have a tail like a comet but much brighter and bigger. It lasted only five seconds. We were lucky enough to see a few more meteors before we went in, but the first one was the biggest.

Later I found out that this particular meteor shower had more meteors than usual because Earth was passing through a concentration of comet debris. Some of the "fireballs" looked huge, but most were really no bigger than grains of sand.

MATTHEW TOOMEY
POOLESVILLE, MARYLAND

What proof do we have for an asteroid impact wiping out the dinosaurs? You could call it extraterrestrial fingerprints. This is the evidence put forth by the father and son team of Luis Alvarez, Nobel Prize-winning physicist, and Walter Alvarez, a geologist. Starting in the late 1970s, the team discovered that concentrated amounts of iridium (a rare element more commonly found in meteorites) can be detected in a layer of clay in Earth's crust. More importantly, this thin layer of clay containing the iridium deposit marks the boundary between the end of the Cretaceous era (K)—when dinosaurs roamed Earth and then vanished—and the beginning of the new age, the Tertiary (T) period.

The scientific sleuths found similar concentrations of iridium in the K-T boundary on a worldwide basis. One by one, possible sources for the iridium deposit were rejected by the Alvarez team. They were left with one plausible delivery route: it came from inside the solar system. Their theory was that Earth had been struck by a hefty-sized asteroid or comet, a "terminator rock" as it has been called. The environment of our planet was a casualty. Nearly 75 percent of life on the globe became extinct, including the dinosaurs who had lorded over Earth for 150 million years.

The Yucatan peninsula of Mexico has been singled out as the spot where an extraterrestrial object struck Earth and possibly triggered the mass extinction. The Yucatan impact crater, at a site called Chicxulub on the north coast of the peninsula, is more than 180 miles wide and is now buried beneath about 2 miles of sediment. Debris from the impact has been found at many sites in the Caribbean and the region around the Gulf of Mexico, as well as in the western United States. ■

STUDENT VOICES



When I saw a meteor, it looked about the size of a basketball or soccer ball. My friends and I were going into our school for a dance right after a nighttime football game. We heard a strange noise and looked up. The clouds were kind of greenish, then a "neon" green streak came out from behind a cloud. The streak was on a steady course. It looked like it would never land. All of a sudden, the streak disappeared into another set of clouds. At first, I thought the streak was a flare or firecracker set off by the other team or their fans, because it was green just like their jerseys. I was surprised to find out from the news that I had seen a meteor.

FAITH EVANS
DICKERSON, MARYLAND

IN THE NEWS

Did the dinosaurs suffocate?

By Tim Friend
USA TODAY

The end of the dinosaur era was marked by a rapid decline in atmospheric oxygen — creating an environment in which wheezing giants roamed, too tired to compete, a new theory says.

"If you're chasing down dinner and pass out before you get to eat, that would not enhance survivability," says Gary Landis, U.S. Geological Survey in Boulder, Colo.

Researchers analyzed ancient gas bubbles trapped in amber. Results, reported Wednesday at the Geological Society of America meeting, shows oxygen levels declined rapidly before the dinosaurs disappeared.

Why did the decline occur so fast? Landis and his colleagues say the air was rich with oxygen because volcanic activity pumped out carbon dioxide, which was converted to oxygen by plants.

When the volcanic "super plumes" shut down, carbon levels fell, plant life declined and oxygen levels dropped.

That seems to have happened over 6 million years about 65 million years ago.

The main competing dinosaur theory: They died after an asteroid hit the Earth and dust clouds blocked the sun.

USA TODAY, 1993

APPENDIX G

STUDENT INTERVIEW QUESTIONS – QUESTION LESSONS

Appendix G

Student Interview Questions – Question Lessons

1. What do you think of the lessons on asking good questions? Do you think they will be useful to you?
2. Is there anything that is still confusing to you?
3. What kinds of questions do you think that you ask most often?
4. Are you motivated to ask better questions?
5. If you could ask me a good question about questions, what would it be?!

APPENDIX H

METEOROLOGY UNIT DISCUSSION QUESTIONS

Appendix H

Meteorology Unit Discussion Questions

Pre-written questions are indicated with an asterisk*.

Other questions occurred spontaneously.

Air Pressure and Heat Transfer:

*What is the composition of the atmosphere? (M)

What are some of the trace gases? (M)

*How do we know that air has mass? (R)

*What is air pressure? (M)

*What do we use to measure air pressure? (M)

*What is density? (M)

*How does density of air affect air pressure? (R)

If we have air that is more dense, what can we say about the pressure that it exerts? (R)

*What are the three factors that affect air pressure? (M) (Break down into three questions.)

*Is the air pressure more or less at the top of a mountain or at sea level? (R)

*Why is air pressure lower at the top of a mountain? (R)

*How is the force of gravity related to air pressure? Why is there more atmosphere closer to the Earth? (R)

*Does warm air exert more or less air pressure than cold? (M)

*Why is it that cold air exerts more pressure than cold? (R)

*If the particles are less spread out, what can we say about the density of cold air compared to warm? (I)

*What is the way in which heat is transferred from the sun to the Earth? (M)

*What part of the Earth's surface receives indirect energy from the sun? (M)

*What part of the Earth's surface receives direct energy from the sun? (M)

So does that direct sunlight affect that region of the Earth? (R)

What is another heat transfer method? (M)

*How is thermal energy transferred by conduction? (R)

What is relationship is necessary between two objects in order for conduction to take place? (R)

*You have the Earth heated by thermal energy. What does it conduct that energy to? (R)

*What heats up faster: sand/soil/rock or water? (M)

Why does sand/soil/rock heat up faster than water? (R)

*Is a hot material more or less dense than a cool material? (R)

We have the ground and the water heating up. We have the air above the ground and water heating up by conduction. What happens to the heated air? (I)

*What happens in convection? (M)

*How and why is the Earth heated unevenly? (I) (There are at least two answers.)

*If Brazil is on the equator and is land, how is its air different from the air off of its coast? (I)

*How can we compare the air over Brazil to the air over Ohio? (R)

*Compare the air over Ohio and Hawaii. Where will the air be warmer? (R)

*When the earth turns, and we're no longer facing the sun, what happens to the air? (I)

*What happens to the air over the Earth then? (I)

*So, at night why doesn't the temperature drop 100s of degrees? (I)

*How does a greenhouse work; why can we grow flowers in the winter in one? (R)

Why does the heat stay inside of a greenhouse? (R)

Looking at this model [of the Earth-sun greenhouse relationship], what do you think is happening? What is modeled here? (R)

Is the sun's energy leaving the atmosphere? (M)

*What do you think Earth would be like if there were no greenhouse effect? Could it sustain life? (I)

*Does dry air exert more or less pressure than wet/humid air? (R)

*Why does wet air exert less air pressure than dry air? (R)

Humidity:

* Is humid air more or less dense, that is, have more or less air pressure than dry air? (M)

What is water made of? (M)

*What is the chemical formula for water? (M)

If it's H_2O, then what do you have two of? (M)

*Why are the water particles lighter than the other gas particles? (R)

What is water vapor? (M) **Note: Basic misconception here. Students seem to think that water vapor is something different from other gases. They tend not to realize that water vapor is a gas just like oxygen or carbon dioxide is.**

How is water gas or water vapor different from liquid water? (R)

Why would a liquid change into a gas? (R)

*What happens to liquid water when it receives thermal energy? (I)

*In terms of particle motion, what does evaporation mean? (R)

You said that nearer a coast, the air is more humid. How did the water get in the air? (I)

What is it like higher in the atmosphere [in terms of temperature]? (M)

What does it mean to condense? (M)

So, if the particles get closer together, and they slow down, what are they now? (I)

Once you have all those liquid particles in the atmosphere, what do they form? (I)

*So, what is a cloud made of? (R)

When air is cold, can it hold more or less water vapor or water gas? (R)

What is dew? (M)

Why does dew form? (R)

What is humidity? (M)

What is relative humidity? In other words, what does the word ‘relative’ mean when describing moisture in the air? (R)

APPENDIX I

METEOROLOGY UNIT WRITTEN QUESTION PROMPTS

Appendix I

Meteorology Unit Written Question Prompts

At the conclusion of inquiry lab (heat transfer by radiation), answer the prompt: Something I learned is … (Open)

If you were a water molecule, how would evaporation feel? Write a first person account in terms of particle motion. (I)

Why is the greenhouse effect necessary to maintain life on Earth? (R)

APPENDIX J

SUMMATIVE ASSESSMENT EXTENDED RESPONSE QUESTIONS FOR COMPARISON – ELECTRICITY VS. METEOROLOGY

Appendix J

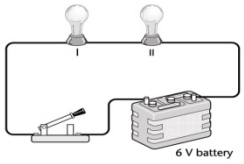
Summative Assessment Extended Response Questions for Comparison – Electricity vs. Meteorology

Electricity:

Relational Question – How does a circuit breaker help to protect against circuit overloads?

Inferential Question –

If one bulb in this circuit burns out, how will the other bulb be affected? Explain your answer.



Evaluative Question – It is the bicentennial year for the town of Parkside, and many celebrations are planned. The mayor wants to protect a very large, historic tree in the center of town because it was there when the city charter was first signed 200 years ago. Ben wants to protect the tree with a steel lightning rod pushed up through its center. John, on the other hand, wants to protect it by clearing all of the other vegetation that is around it, so it stands majestically alone in the center of the town square. Which solution do you think would be the most effective in protecting the tree? Explain why you think so.

Meteorology – Summative Assessment 1 (Background Science – air pressure, heat transfer, water):

Relational Question – What are the three ways in which the sun's energy arrives at the Earth, heating it and then the atmosphere. Use a labeled diagram to illustrate your explanation.

Inferential Question – What would it feel like to be a water molecule during the course of the water cycle? Describe the particle motion of water molecules in an ocean, the atmosphere, a cloud, and in rain; be sure to name the state of matter of each.

Evaluative Question – Lara has asthma (trouble breathing), and her employer wants her to move to Denver, Colorado, nicknamed the "Mile High City". Considering what you know about air pressure, do you think Lara should move there?

APPENDIX K

SUMMATIVE ASSESSMENT QUESTIONS FOR COMPARISON – 2011 AND 2012 METEOROLOGY

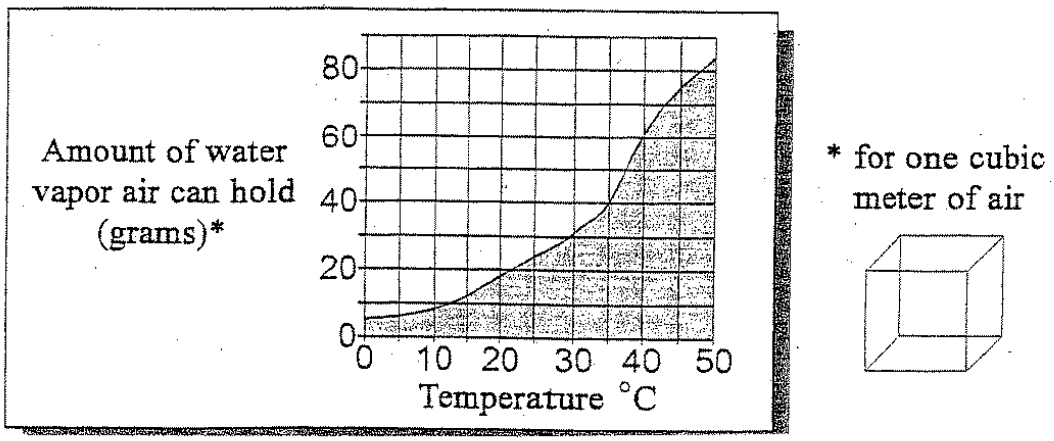
Appendix K

Summative Assessment Questions for Comparison – 2011 And 2012 Meteorology

1. A cloud is made of
    a. water vapor.
    b. liquid water.
    c. gaseous water.
    d. both a and c.

    Note that this question is the target question that most often indicated students' misconception about the nature of water vapor.
2. Each water molecule is composed of two atoms of hydrogen and one atom of oxygen. This means that water is
    a. always a liquid.
    b. not very dense.
    c. very dense and heavy.
    d. an element.
3. When thermal energy is added to a liquid, that liquid
    a. evaporates.
    b. condenses.
    c. precipitates.
    d. freezes.

4. What pattern do you observe in the graph; that is, how are temperature and water vapor related?



APPENDIX L

SUMMATIVE ASSESSMENT REFLECTION CHECKLISTS

Appendix L

Summative Assessment Reflection Checklists

2011 - The materials that were most helpful to me in learning about meteorology were:

_____ taking notes

_____ watching DVDs (the water cycle)

_____ doing labs (evaporation, condensation, relative humidity)

_____ reading the textbook

_____ doing section review questions

_____ math practice

_____ doing practice worksheets

2012 – The materials that were most helpful to me in learning about meteorology were:

_____ taking notes

_____ watching DVDs (forecasting, the water cycle)

_____ doing labs (evaporation, condensation, relative humidity)

_____ reading the textbook

_____ doing section review questions

_____ math practice

_____ doing practice worksheets

_____ interpreting diagrams (heat transfer, reflection of sunlight, greenhouse effect)

_____ referring to binder table of contents and learning objectives on Dr. Schoeffler's webpage

_____ asking questions (muddiest point slips)

_____ reflections (half-sheet questions)

_____ graphing observations (direct/indirect light, heating of soil/water)

APPENDIX M

SUBJECT CONSENT FORMS

Appendix M

Subject Consent Forms

SUBJECT CONSENT FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY

USING TRAINING IN METACOGNITIVE SKILLS

TO ENHANCE CONSTRUCTIVIST LEARNING

You are being asked to participate in a research study about how you learn and whether you can learn to monitor your own understanding of new ideas. The research study will be integrated into your science classes, so you will not really notice any differences in class. However, there will be occasions when audio-recordings are made of classroom discussion; there will be two times when you are asked to participate in an online, anonymous survey; and some of your written responses and tests will be reviewed for evidence of what you have learned.

Any references made to you will be anonymous; in the final report you will be referred to by a pseudonym (that is, a made-up name). Participation in the audio-recording is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at anytime. The surveys are also voluntary, and you may choose not to complete them. **Participation or non-participation will not affect your grade or class standing.**

There are no costs to you and no risks to you. The benefit to you may be that you become better at understanding how you learn and how you can help yourself to learn new ideas more effectively. I will explain after the study (after spring break) if I have found that my lessons seemed to help you learn new things more easily. I will also ask you your opinions about whether or not you think I am correct!

If you or your parents have any questions about this study, you may ask me or Mrs. Alestock.

Sincerely,

Dr. Schoeffler

"AUTHORIZATION: I have read the above and understand the discomforts, inconveniences and risks of this study. I, _____ *(name of parent or guardian)*, related to the subject as _____ *relationship*, agree to the participation of _____ *(name of subject)* in this research. I understand that the subject or I may later refuse participation in this research and that the subject, through his/her own action or mine, may withdraw from the research at any time. I have received a copy of this consent form for my own records.

Parent or Guardian Signature: _____

Child's Assent Signature: _____

Witness: _____

Investigator: _____

Date: _____ ."

SUBJECT CONSENT FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY - Interviewees

USING TRAINING IN METACOGNITIVE SKILLS

TO ENHANCE CONSTRUCTIVIST LEARNING

You are being asked to participate in a research study about how you learn and whether you can learn to monitor your own understanding of new ideas. The research study will be integrated into your science classes, so you will not really notice any differences in class. However, there will be occasions when audio-recordings are made of classroom discussion; there will be two times when you are asked to participate in an online, anonymous survey; and some of your written responses and tests will be reviewed for evidence of what you have learned.

Any references made to you will be anonymous; in the final report you will be referred to by a pseudonym (that is, a made-up name). Participation in the audio-recording is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at anytime. The surveys are also voluntary, and you may choose not to complete them. **Participation or non-participation will not affect your grade or class standing. Furthermore, you will be asked to volunteer in three voluntary interviews that will take place at lunch time in Dr. Schoeffler's classroom.**

There are no costs to you and no risks to you. The benefit to you may be that you become better at understanding how you learn and how you can help yourself to learn new ideas more effectively. I will explain after the study (after spring break) if I have found that my lessons seemed to help you learn new things more easily. I will also ask you your opinions about whether or not you think I am correct!

If you or your parents have any questions about this study, you may ask me or Mrs. Alestock.

Sincerely,

Dr. Schoeffler

"AUTHORIZATION: I have read the above and understand the discomforts, inconveniences and risks of this study. I, _____ *(name of parent or guardian)*, related to the subject as _____ *relationship*, agree to the participation of _____ *(name of subject)* in this research. I understand that the subject or I may later refuse participation in this research and that the subject, through his/her own action or mine, may withdraw from the research at any time. I have received a copy of this consent form for my own records.

Parent or Guardian Signature: _____

Child's Assent Signature: _____
Witness: _____
Investigator: _____
Date: _____ ."