Think! Teaching Logic in the Elementary or Middle Grades Classroom

Sherri Bernier-Lucien

Rationale: Why Teach Logic?

Crime is common. Logic is rare.
Sherlock Holmes
In “The Adventure of the Copper Beeches”

Is it necessary to teach students to think logically, or is logical thinking a natural part of human growth and development? Certainly as children grow they do become more logical thinkers. Anyone who has ever spent any time with a toddler can tell you that children’s logic improves with age. But does that natural development alone prepare students for the kind of logical thinking that will help them make decisions as adults? I would contend that for many students it does not. Take Harold Camping, who using calculations from a biblically based calendar, predicted The Rapture would take place on May 21, 2011. Many adults gave vast amounts of money and traveled many miles on the word of this man. I believe most of us would consider such actions as rash and illogical, but at the time, many otherwise reasonable adults believed The Rapture would occur. The words of Mortimer Adler adequately express the condition these people found themselves in, “Not to engage in the pursuit of ideas is to live like ants instead of like men.” And like so many ants they filed along believing the world would end for them as they were transported to a better life elsewhere. And this is not an isolated incident. Consider the people of Jonestown, or the many people who followed Hitler. Those are some extreme examples, but people often make illogical decisions in their everyday lives as well. Even well informed people are prone to making illogical decisions about how and when to use credit or whether or not they should schedule a yearly medical exam. Even Dr. Mehmet Oz, the renowned medical doctor who gives medical advice to millions, procrastinated nine months on a follow up colonoscopy! This is a person who had all the information necessary to make a logical decision, but still did not. These are the types of decisions all of our students will be faced with as adults, but without the knowledge of how to think logically, and what prevents it, many students will grow to make such decisions very poorly. Perhaps if logic and thinking had been a stronger part of the curriculum for the followers of Camping they would not have the regrets many are now experiencing.

Despite the examples above, most of us consider ourselves to be logical. Indeed, to be told you are irrational or illogical is considered very insulting, but mistakes in logic are extremely common. As it turns out, logical thinking is actually rather difficult, and humans are wired in ways that often counter act our desire and ability to be logical. In Deborah J. Bennett's book, *Logic Made Easy: How to Know When Language Deceives You*, she makes the case that logical thinking is not a naturally occurring ability in humans like walking or talking, but a foreign way of thinking that must be specifically taught in order to be grasped and practiced in order to become proficient[1]. She points out that on tests such as the Praxis, the Graduates Record Examination (GRE) and the Law School Admissions Test (LSAT), the sections on analytical thinking and logical reasoning are the most difficult for examinees. But aren't humans considered logical creatures? Aren't we supposedly the only organisms on Earth who have developed the ability of rational thought? I cannot really say whether other living beings think rationally or not, but I know my students often do not! According to Maurice Finocchiaro, people often make mistakes in logical reasoning due to ignoring available information, adding background knowledge of their own, an inability to organize and track information, or an inability to retrieve information[2]. These are all areas in which we can teach students thinking skills and organizational tools for overcoming such obstacles.

Other researchers have delved into why we often make illogical decisions even when we do have all the information and the ability to reason through a problem. It turns out we are simply wired to think illogically in some circumstances. In his book, *The Believing Brain*, Michael Shermer reveals that people do not generally gather the facts and then make a logical decision, but instead first hold a belief and then gather facts to support it[3]. Anyone who has ever tried to convince an eleven year old that all objects fall at the same rate understands how hard it is to get someone to look at a problem logically when they already believe they know the truth! Shermer explains that we have evolved to look for patterns. Sometimes these patterns are real and valuable. A rustling of the grass, for example, may mean an approaching predator. Sometimes the patterns are false, such as having your team win the Super Bowl while you were having a plate of spicy nachos. Shermer calls this patternicity and argues that natural selection for this trait is the basis for why many people believe in miracles, magic, and superstition.

Our brain's inability to calculate probability works against us as well. Many people believe in urban legends such as the one that contends couples who have trouble conceiving and adopt a child will often end up conceiving after the adoption because they no longer feel the stress to conceive. People believe such ideas because they have heard of it happening. Indeed, I know of a couple who did conceive only months after adopting. Stories of such events make the news because they are fascinating, but no one reports that they did not conceive after adopting a child. Obviously not conceiving after adopting is quite a common occurrence, but we often base our beliefs on one instance where we identified a pattern rather than a conclusive body of data.

If Shermer's findings about the formation of beliefs and Finnochiaro's list of our brains' shortcomings in logic are not enough, Tali Sharot throws up another barrier to logical thinking with what she refers to as the Optimism Bias. This is the same type of belief we always accuse teenagers of when we claim they believe themselves untouchable and immortal. It is the “it will not happen to me” rationalization. Apparently we do not out grow it. In many ways optimistic thinking is healthy even when it is not realistic. Sharot claims that people who evaluate their life in the most realistic way usually are accurate in the future outcome[4]. However, these people also tend to be mildly depressed. Turns out being very logical comes at a bit of a price, but so does being irrationally optimistic. The belief that everything will turn out fine in my life even though it does not in others’ is what caused Dr. Oz to put off his follow up colonoscopy, a decision that could have had life ending results[5]. Sharot says that awareness of the Optimism Bias is the best way to avoid its negative consequences. The upside is that awareness of it will not make you less optimistic, but it may give you the edge to evaluate your decisions more logically; to believe you will avoid cancer and still get that colonoscopy.

Unit Design

In this unit I have not designated the teaching of logic to specific lessons to take place at a certain time of the day or week. It is not a unit that has a beginning or end like a unit on the Civil War. Instead it is a way to permeate your entire day in every subject with logic. But the best way to become a better teacher of logic to your students is to improve your own skills in logical thinking. In this endeavor Bennett’s book is a good way to begin. The first section of this unit will give suggestions for teaching logical thinking and organizational strategies to help overcome the pitfalls to logical thinking that occur due to a lack of reasoning. In the second section I will give ideas for helping students become aware of what causes them to make illogical decisions, like Shermer’s concepts of belief reinforcement and Sharot’s idea of an evolutionary bias toward an irrational level of optimism.

Population

I teach in a suburban school in a large school district in the southeast. My homeroom class has 27 students and is heterogeneously mixed for all subjects except math. In math we group our students by ability across the grade level. I teach the academically gifted math class to 34 students. I do not believe the strategies and activities in this unit are limited to such a narrow population. All children need to learn how to think logically, and this unit is applicable to all students in the upper elementary and middle school grades. High school students could also benefit from many of these activities and strategies, but it would be my hope that more formal instruction would be available to students at that point.

Math

Syllogisms

Math is probably the area where the most specific and direct instruction in the teaching of logic can occur. In the formal teaching of logic students study syllogisms in their many figures, moods, and atmospheres. This can be reduced to what amounts to memorization and skill and drill, taking out much of the thinking that is the point. However, you can use syllogisms in your math class with just a few basic principles. A syllogism has at least two premises followed by the conclusion that the student must draw from the premises. Together the premises and resulting conclusion make either a valid or invalid argument. For example:

All numbers that end in 0, 2, 4, 6 and 8 are even.
All numbers evenly divisible by ten end in 0.
Therefore, all numbers that are evenly divisible by ten are even numbers.

This argument is valid because the conclusion must be true if we accept that the premises are true. However, the conclusion "all numbers that are evenly divisible by ten are also divisible by 5" is invalid. Although it is a true statement, it does not follow the given premises.

The use of "all" or "none" makes the premises universal. Premises can also include "some" or "most" instead of "all" or "none". "Some" and "most" are called existential quantifiers. Premises that use the term "some" or "most" are said to be particular in nature rather than universal. Syllogisms that include the term "some" or "most" can be trickier to follow:

All layered clouds have stratus in their name.
Some stratus clouds produce rain.
Therefore, some clouds that produce rain have stratus in their name.

This may look a lot like proofs in geometry, and it should as proofs are syllogisms. Some may think that this type of thinking should be reserved for the high school student, but I believe there is also a place for this type of thinking in the upper elementary and middle grades classroom as well. An earlier familiarity with this form will be helpful to students later in classes like geometry as well as many placement exams for entrance into college and graduate school programs.

In math there is a lot of classification that can be worked out using this tool of logic. Imagine this scenario in your classroom. You are working on classifying quadrilaterals as part of the fifth grade curriculum and want students to realize that a square is a rhombus. Present the following premises and have students discuss in class which one is correct.

Premise: All rhombi must have four equal sides.
Premise: All squares must have four equal sides.
Premise: All squares must have 4 right angles.

Based on these three premises which conclusion can be drawn:

All squares are rhombi
All rhombi are squares

Research shows that even adults have trouble with syllogisms, even though they seem fairly straight forward on the surface. To help students navigate the logic behind the fact that all squares are rhombi even though all rhombi are not squares have manipulatives available so they can build rhombi and squares to test their ideas. Research suggests that visuals and manipulatives greatly increase a person's ability to correctly draw conclusions from premises. In Guy Politzer's research on logic he found subjects were highly successful at finding a counterexample that would disprove a statement when a visual accompanied the problem. Likewise, John Venn, the creator of the Venn diagram, found success in teaching his pupils logic when he created his famous diagrams to help them solve syllogisms. (Politzer, 1981)

Geometry is not the only place where syllogisms can be used in math. Anywhere in math that you can put down a premise a syllogism can be formed.

Premise: All even numbers have the number 2 as a factor
Premise: All numbers except the number 1 have two factors: 1 and the number itself
Premise: Prime numbers have only two factors: 1 and the number itself
Premise: 2 is a prime number

What conclusions can be drawn?
1 is not a prime number
All even numbers except the number 2 are not prime numbers
All prime numbers are odd except the number 2

Imagine the discussions your children would have to have with each other and the logic they would have to employ to come up with such conclusions about quadrilaterals and prime numbers. While it might be faster to simply present them with these facts thinking through these concepts will give them the experience to truly understand the information and the practice to use logic in the future when life does not simply present all the facts.

Another good strategy is to let students make their own syllogisms and have other students decide if they are valid or invalid. If they are invalid students could help each other tweak them to make them valid. The book *Logic Anyone?* By Beverly Post and Sandra Eads is a good source of readymade syllogisms to get you started. It also has some introductory material to help your students understand what syllogisms are and how to use them.

Matrices

A matrix is a math puzzle where clues are presented and students use a matrix, or grid, to keep track of the clues in order to solve the puzzle. An example of a matrix puzzle has been included in the activities section. If you have never seen one I recommend you view it before reading on. In order to give students a chance to use their logic and articulate that logic with others I suggest using matrix problems in the following way.

1. Display the matrix on an overhead or interactive whiteboard. Have students copy the matrix onto graph paper or provide them with a copy.
2. Give students ten minutes to work on the matrix independently. This allows them to exercise their own logic.
3. After ten minutes have them use the next ten minutes to talk about the puzzle in small groups. I like groups of 3 to 6 students. This gives them an opportunity to articulate their thinking and speaking out loud helps students clarify their thinking while the input of peers can help students see errors in their logic.
4. After this have students come to the interactive white board or overhead and make a move on the grid there. Before putting an X or check on the board they must be able to articulate to the class why it is a valid move. The rest of the class must agree that the move is a logical conclusion based on the clues and the condition of the grid at the time of the move.

Sudoku

A currently popular logic puzzle is the Japanese Sudoku puzzles. Although not strictly a mathematical puzzle as any symbol could be used instead of numbers, they still help students work on logical thinking. I recommend using them, but I also believe it is helpful to support students in the strategies they need to employ to solve these puzzles. After students have had a chance to work out some of their own logic in solving these puzzles have students share how they solve these puzzles in much the same way you did on the matrix. Display a puzzle students have had a chance to work on and have students come up and justify the placement of a number in a square. You can then articulate what type of logic the student was using. After a few puzzles students should be able to articulate the type of logic strategy they are using for themselves. Below are the types of logic generally used in solving Sudoku puzzles.

- Eliminate Digits: The elimination of all other possible digits for a cell leaves only one digit to go in that cell.
- Eliminate Positions: If a digit cannot go in any other cell in a row, column or box then it must go in that cell.
- Eliminate from Partial Positions: You may not know exactly which cell a digit

must go in, but if you can get it down to two or three positions within a row or column you will find it may eliminate it as a possibility in other cells within a box. For example, if it must go in one of the bottom two cells of a box because it is the only place for it in the corresponding row or column then it cannot go in one of the cells in the top row of a box.

- Eliminate from Partial Digits: If you can get two cells in a row, column, or box down to only two choices, say 6 or 9 could go in either one, but all other digits have been eliminated then you can eliminate 6 and 9 from all the other boxes in that row, column, or box.

These strategies will work to solve most of the easy to difficult Sudoku puzzles. I would not provide these strategies up front to students, but allow them to discover them and then name them so they can refer to these moves as they discuss solutions to puzzles. You do not need to name them exactly as I have. It would be best to let the students name them. After they have been discovered you can post them in the classroom for students to refer to. For a more complete description of these strategies, plus a more involved strategy for the really fiendish puzzles, you can go to http://www.logicgamesonline.com/sudoku/tutorial.html. The website will also give a visual that will help you navigate these strategies if the descriptions alone are not clear to you.

Math Olympiad

Another great resource for increasing logical thinking in the mathematics classroom is Math Olympiad. This program does not require students to use computation above their grade level, but every problem forces students to use logic rather than an algorithm to solve it. It is a good example of adding depth instead of breadth to the curriculum. So often with gifted math students teachers feel the only thing to do with them is to move on to computation from the next grade level's curriculum. This simply is not so. Though I am not opposed to moving on to above grade level topics at all, students should not be skilled and drilled into the next level of computation without taking the opportunity to deepen their understanding of the math at their grade level.

Present a Math Olympiad problem and after students have had time to work on the problem have students share various ways they went about solving it. Students are amazed at how many different ways there are to work the same problem. The book offers an answer key, but also a section where you get several different ways of solving the problem so you can share them with your class. There is also a section that offers hints if your students get stuck and cannot seem to move on.

Math Olympiad is actually a competition between schools. Your class can form a team and submit scores for monthly contests or you can simply purchase the books and use the problems in your classroom. To get started simply go to http://www.moems.org/ and enroll. You can also purchase books at this site if you do not wish to participate in the competition.

Language Arts

Analogies

Analogies are puzzles based on identifying relationships between two items and then having the ability to apply that relationship to a separate set of items. To help students master analogies I use the "Make a Sentence" technique. For example after reading a selection about how the people of Kashmir use boats called shikaras as their major form of transportation they were asked to identify a pair to complete an analogy of the people of Kashmir's houseboats to their shikaras.

Houseboat: shikara :: ______________ : _______________

Before I would have students even look at the possible choice I would have them create a sentence that shows the relationship the two items have. One possible sentence is:

A Houseboat is where the people live and the shikara is their transportation.

It is very important that you keep the terms in order as order matters in an analogy. It would not be acceptable to reverse the terms in a sentence like:

A shikara is a type of transportation someone living in a houseboat uses.

Although it conveys the same meaning this could lead them to pick an answer where the terms were reversed which would be incorrect. The answer should have the same relationship in that it is a type of housing and the transportation that a person in that type of housing would likely use. It should fit into the exact same sentence rather smoothly. For example the correct choice to this analogy was:

Houseboat: shikara :: apartment : car

The corresponding terms fit into the sentence in the same order:

An apartment is where people live and a car is their transportation.

Some of the most common analogies involve relationships that are synonyms, antonyms, cause and effect, worker and tool, worker and object he creates, part to whole, mathematical relationship, classification and type, and degree of intensity. Each of these can, of course, be reversed, and they are only some of the many relationships that are possible. The usefulness of the sentence technique is that it is a way for them to define the relationship without having to identify exactly which type of relationship it is. By forming the sentence they are defining the relationship, but in a less abstract way.

Inferences

To make logical inferences while reading students must make connections between the clues the author is presenting and experiences from their lives. There are many pitfalls for students when trying to form inferences. For one they are often unaware that the author is doing something intentional when he or she places a clue in the text. Until it is pointed out to them, students do not realize there is more to reading than a literal interpretation of the words on the page. Many students do not draw upon the background knowledge needed to make the inference, or they lack the background knowledge all together.

When discussing text with students we need to bring up the author often so students grasp that the author's choices are intentional. Why do you think the author chose to do this or have the character do that? Students do not realize that these are choices the author made. They attribute the actions and events in the book to the situation or the choices of the character, but immature readers do not recognize the author is the one who chose to make those events happen. If a tornado occurred in the story it is not because of the weather, but because the author chose to have it happen. Why? How does that affect the story? I remember a telephone conversation my mother was having one day where she mentioned what a good actress Katherine McGregor, the actress who played Mrs. Olsen on the show *Little House on the Prairie*, was. She mentioned how she was so good that my sister and I loathed her. It clicked with me right then how naïve I was. I knew the woman was an actress playing a part, but it never occurred to me to separate her from her *role* on the show. At that moment I realized she was probably a very nice person that I hated for her extraordinary ability to act. I was about 11 years old when this realization came to me because of a chance phone call I overheard. Even though the situation was slightly different from separating the author of a text from the characters they create, it made me realize that characters do not make their own choices. There is a bigger picture going on, and I started looking for it. This is the light bulb that children need to have illuminated before they can really understand text beyond the literal level. Until students realize the author is in charge of every word, description, event, etc. they will read right over the clues they need to make inferences from and not think twice about what they might mean.

Background knowledge is the next hurdle. Students need to be made aware that authors of more sophisticated reading material do not spell everything out for them. That they assume their readers have certain experiences from their life that will help them fill in the blanks. It is more interesting when a reader describes a character by saying their eyes fell to the floor then simply saying he was ashamed. The author assumes you have felt ashamed before and seen other people feel ashamed. They expect you to realize from your life experiences that looking at the ground is common when someone feels ashamed.

As inferences become more complicated or if the text is about a topic where students have limited background knowledge then background knowledge will have to be built prior to the students reading of the text.

Once students have these two concepts of author intention and background knowledge they are ready to inference. A good reader makes inferences on the spot as they read and should not need to write anything down as this will just bog down the natural reading process and kill the enjoyment of the text. However, when students are just starting to make inferences or are reading difficult text the following strategy will help them create a mental process for making logical inferences and conclusions from text. I call it the TWI method. The “T” stands for text, the “W” for world, and the “I” for inference. Have them write the letters down vertically to make the following graphic organizer.

T: the text says…
W: in the real world I know that…
I: therefore I can infer that…

Notice that this looks like a syllogism. It follows the same structure. Much of thinking logically is about how a person mentally organizes the facts of a situation. So having a system for organizing inferences will help students work through them. Of course an inference is really a logical possibility while a valid syllogism is a truth such as all squares are rhombi. The benefit of the strategy is to aid students in making inferences mentally. Once the concept is grasped this should cease to be a written exercise!

Science

Dispelling Misconceptions

All the previous ideas in this unit have been activities to promote logical thinking in students, but what happens when students believe they have already thought an idea through and reached a logical conclusion, but that conclusion is actually a misconception? As Shermer points out in his book, *The Believing Brain*, people do not easily give up their beliefs, but instead seek out evidence that will support them while ignoring evidence that suggests they are incorrect. Science is a place where this often occurs for students. They have built up a body of scientific misconceptions that even direct evidence through experimentation often fails to shake. Our students are not alone in this. We are all aware of the plight of Galileo Galilei who was forced to retract his statements about the Earth’s movements even though he had collected very convincing observational evidence to support his claims, and look at how long it took for the Catholic Church to admit the Earth indeed does revolve around the sun! It was not until Pope John Paul II issued an apology to Galileo in 1992 that the Church was willing to publically acknowledge that Galileo was correct!

People are attached to their beliefs in very emotional ways even when those beliefs are not tied to their religion. Students do not mind learning something new they did not know, but they are very resistant to learning something that contradicts what they believed they did know. The perfect example of this is the concept that all objects fall at the same rate due to the force of gravity being consistent on every object. Most students absolutely believe that lighter objects fall more slowly and heavier objects fall more quickly. Why? because they see so many examples in their life where this seems to be the case. Just like watching the sun rise and set seems to prove that the sun is going around the Earth, falling leaves, feathers, paper, and bubbles seem to suggest that lighter objects float to the ground slowly while a baseball falls much more quickly. Students have noticed a valid pattern of what falls quickly and slowly, but incorrectly identified the reason for the difference in rate to the objects' mass rather than their shape!

When I need to challenge a belief like this in science I find that if I tackle it head on it is time consuming and often a losing proposition. In our curriculum we are supposed to help students come to this realization by having them drop a ping-pong ball and a golf ball. When you do you will find that they do indeed fall at the same the rate if you already believed they would. If you do not believe that they will hit together however, it has been my experience that you see that the golf ball hit the tiniest fraction of a second before the ping-pong ball every time. I never see this, probably due to my own belief that they will hit together, but students will swear by it. If they do see the ping-pong ball hit at the same time or before the golf ball then the person who dropped them surely dropped the ping-pong ball just a little ahead of the golf ball. It takes an incredible number of drops and coaching not to look too closely for tiny difference when they hit before some of the students will agree that maybe they do hit at the same time. For others you just have to teach them the rule stated in Newton's Law of Gravitation and appeal to the fact that he was really smart and probably knows more than we do so, we are going to go with he was right. Now that student who still looks at leaves falling and knows they fall slower than a golf ball has not really thought anything through. They just saw a lot of balls drop that convinced them of nothing and memorized a rule that goes against everything they believe.

Now maybe you're thinking, I know a few fifth graders who know that all objects fall at the same rate. I do too. They have seen it on TV or read it in a science textbook and they believe it because they have faith in the scientists to be right. I have yet to meet the fifth grader who *understands* that all objects fall at the same rate. I am sure there are a few out there, but you are unlikely to get 25 of them in your next science class. So how do you teach science concepts that appear counterintuitive? Ask a different question! I have learned not to go head to head with students' science misconceptions, but to side step them. I never ask students whether the golf ball or the ping-pong ball will hit the ground first if dropped from the same height. I ask them where they have to drop them from to get them to hit the ground at the same time! We measure the mass of both balls and groups go off and perform all kinds of calculations to see how much higher they think they have to hold the golf ball than the ping-pong ball in order to get them to hit together. Gradually the distance between the balls grows smaller and smaller as they try to get it to work and then Eureka! It hits them. You have to drop them from the same height. There is a buzz of energy around the room and everyone starts trying this and it works! They do not even yet realize at this point that this challenges a belief that they hold *because you never asked them the question that their previous experience would solidify into a belief*. But you have created a new pattern for them to form beliefs around before you challenged their belief. At this point we still do not state that all objects fall at the same rate or that lighter objects do not fall slower than heavier objects; instead, we start dropping different things. We mass textbooks, pens, pencils other types of balls, even people, and we find that to get anything to hit at the same time all you have to do is drop it from the same height. It will be the following day before I suggest the experiment to see which will fall faster the ping-pong ball or a golf ball. Inevitably the students do not see the point in doing it. Don't we all already know that all objects fall at the same rate regardless of their mass!

Of course then we do have to take on air resistance so we can figure out why those pesky leaves just do not seem to follow the rules, but that is for another lesson! Now that they believe all objects do not fall at the different rates due to their mass, they will be open to finding out what does cause things to fall at different rates since it is *obviously* not their mass. And obviously is a very important word. You want your students to say *obviously* things do not fall at different rates because of their mass, because this suggests they get it rather than they have memorized it!

Look for the concepts in your own science curriculum that are hard to get students to buy into. See if you cannot change the structure of what you are asking or what they are experimenting to side step their currently held beliefs. By building evidence that will act as counter experience before confronting their belief, you will find they will give up the old belief much more quickly and completely, sometimes without even noticing that they ever believed anything else at all.

Constructing Hypotheses and Conclusions

Making a hypothesis is an important part of the scientific process, but it is problematic with younger students. Often you reinforce negative self concepts in students when they always seem to form the hypothesis that is proven wrong and certain other students form the hypothesis that is proven correct. For this reason I never have students write an individual hypothesis for an experiment. We always form a class hypothesis. That way we are all correct or incorrect together. Also, since I am part of the hypothesis-making process they get to see my reaction to our hypothesis when it is incorrect. I always have a very excited reaction when our hypothesis is wrong. After all, this means we learned something we did not know, and/or got results we did not expect. If experiments always do what we expect then we are not really learning anything!

To form the hypothesis I use an *if, then, because* format. Many times a hypothesis in younger grades is simply written *if/then*, if I do x then y will happen. By leaving out the *because* there is no critical or logical thinking going on. When we make a hypothesis in my class we list all possible outcomes that the students can think of on the board. Then we brainstorm experiences we have had that would lead us to accepting one of these outcomes as more or less likely than the others. Everyone's ideas go on the board. Then we use these experiences and try to determine what science might be behind it. For example, when we were doing an experiment in class on the rate at which land and water heat and cool, many students came up with experiences about cool pool water and hot pavement. They decided this may be because dark colors absorb heat better than light colors, a fact they had learned in an earlier grade. So we hypothesized that land heats more quickly than water. They also had examples of snakes coming out at night to absorb the heat from the road. This led them to believe that since the road had heated more than the water it would cool down more slowly. Our hypothesis was half correct and half incorrect, land does indeed heat more quickly, but it also cools more quickly as well. The fact that they had thought through the because hypothesis actually opened them up to a better understanding when they were proven wrong. When the data came in and we discovered part of our hypothesis was incorrect we re-brainstormed to see if we did have any experiences that could be used to show that land heats up quickly *and* cools off quickly. We found we could! We had just recently read a story about the desert and found that a desert quickly heats up very hot during the day that at night temperatures can be below freezing. Another student verified this to be true from an episode of *Man vs. Wild* where the star, Bear Grylis had to survive in a desert where he did indeed have to contend with intense heat during the day and temperatures below freezing at night.

At the end of the experiment I always have students write a conclusion that answers four questions:

1) Did the results agree with our hypothesis?
2) Why do I think we got the results we did?
3) What experiment would I test next?
4) How can I use this information in the real world?

When we re-brainstorm at the end of the experiment students are supported in answering question two. In this case they can use the information about the desert to help them develop a reasonable argument, but question number four is often a challenge for them. They have experiences in their life that relate to this information, but as Finnochiaro points out people often have trouble retrieving information that would be helpful in solving problems. I insist on this question because I want students to build a strong sense that what they learn in science class affects other aspects of their life. I find that a simple graphic organizer where they list areas of their lives that relate to the science concept under investigation is helpful to students by helping them retrieve their background knowledge on the topic. For this experiment we had a graphic organizer split into four areas. Each area showed a result of the experiment. This is an example of one of my student's graphic organizers. I try and have students come up with two or three bullets for each section of their graphic organizer, but many found the section on water cooling slowly to be a challenge. This helps explain why they did not successfully predict that water cools slowly in their hypothesis.

Land heats fast • Hot roads • Hot beach sand	Land cools fast • Desert temps at night • Metal gets cold fast
Water heats slowly • Frying pans heat faster than water boils • Pool water is cooler than the concrete around it	Water cools slowly • It takes a long time for soup to cool

With the use of this graphic organizer students are much better prepared to answer question four of their conclusion.

So how is the experiment with falling objects different from the heating and cooling of land and water? Students have very strongly held beliefs about how objects fall, while they are fully willing to admit they really have no idea whether land heats or cools faster or slower than water. In the former you have to bypass their existing beliefs where in the latter you have to experiment and root out experiences buried within them to form a belief. The formation of the hypothesis with a *because* step is critical in students' formation of logic. It helps them realize that a *random* guess is not a *logical* guess and that we have to gather and organize our existing information in order to form a logical hypothesis. Being incorrect does not mean we were not logical; it means there was additional information outside of our experience that we still needed to gather in order to come closer to the truth. Is that not the kind of thinking we hope students will learn to engage in as adults? We want them to examine what they already know against new information they now have to form new conclusions that will guide their future decisions.

Social Studies

Answering Unanswerable Questions

What is an unanswerable question? Any question where there is no clear cut answer such as questions involving moral dilemmas, personal values, or what course of action to follow when desired outcomes differ. If there is no correct answer, why ask students to answer them? These are the toughest types of questions we face in our life and we have to face them all the time. Who do I vote for? What school is best for my child? Should I eat meat or not eat meat? There is no one right answer to any of these questions, but the way you make decisions such as these greatly affects the quality of your life. Even though the right answer for me may not be the right answer for you, attacking such issues in a logical and informed way is at the heart of finding the answers that will work in your own life. As most schools move toward the common core curriculum writing argumentative essays will become a priority. The reason argumentative writing is part of the common core is so students will be exposed to considering unanswerable questions. There is really no reason to write an argumentative piece for which there is only one right answer! The writers of the common core realize the importance of teaching children not *what* to think about important topics such as these, but *how* to think about them. Below are a few ways to help students consider unanswerable questions.

Seminar

Holding seminar discussions is often seen as a waste of time because at this time you are not teaching students what to think. We often downplay the necessity of teaching students how to think, but another underrated skill is how to dialogue. Pressure to teach to the test where dialogue is not assessed often keeps teachers as the only truly active speaker in the classroom. Learning how to dialogue in a group and listen to others actively to increase your own knowledge are critical skills for many of the jobs students will compete for in the future. We owe it to our students to prepare them for a work force that has become more group-oriented and less individual oriented. It is true as well that the value of the ideas other people share with them will vary widely. Often another's input opens your eyes to new ideas or ways of thinking you had not considered. Sometimes, however, the other person has no idea what they are talking about or is actively using various types of propaganda to persuade you towards a view that is desirable for them, but not in your own best interest. Taking part in seminar gives students experience in evaluating ideas from their peers for accuracy as well as credibility.

At my school we use the Paideia seminar format developed by Mortimer Adler. This lays out techniques for running seminar, setting personal and group goals, and for mapping responses. It also lays out specific criteria for selecting texts and creating seminar questions. In order to run a seminar in this format you need training. If you are interested in becoming a Paideia teacher you can start by going to the National Paideia website at www.paideia.org. You do not need to use the Paideia format to run successful seminars. If you follow a few basic steps you can easily hold seminars with your students.

The first step is to select a text to be the focus of your discussion. A text could be a poem, short story, novel excerpt, or nonfiction article. A text could also be a piece of music, art work or even a map. Anything that conveys ideas worthy of discussion and that has a good deal of ambiguity will work. Why ambiguity? If all the ideas in the text are direct and need little interpretation then there really is nothing to discuss. Seminar is a great way to pull in social studies as primary documents such as the Bill of Rights or letters from Civil War soldiers make great seminar pieces. One primary document I use every year is the Grievances Against the King section of the Declaration of Independence. I use this piece while we are studying the events leading up to the American Revolution. Once we have studied all the events that led the American Colonies to rebel we look at this document. One of the unanswerable questions I ask my students related to this document is: Which, if any, of these grievances are worth going to war to kill or die for? This is a tough question, but it is the question Americans had to ask themselves as they voted for and against going to war with England, and it is still a relevant question today as we consider with whom we should or should not go to war.

Another important part of seminar is to make sure students feel comfortable to share their ideas and not wait for the teacher to supply the answer. To be sure students take ownership of the discussion and the ideas the teacher should not respond directly to any of the questions. The teacher simply puts forth a question to be discussed and it is then the students' responsibility to hold the discussion. This is the most difficult part of holding seminar for me as there is generally so much I would like to say! However, teacher input shuts down student thinking. There is no reason for a student to think for themselves if they know the teacher will tell them what to think if they just keep quiet for a minute. Students generally sit in a circle for seminar as it promotes face-to-face interaction and they hold their dialogue without raising hands. This requires them to follow polite rules of conversation and group dialogue like politely deciding who will speak first when two people begin speaking at once. Again, too much teacher direction on this part steals the responsibility from the students and returns it to the teacher. The teacher should monitor who has spoken and who has not so they can gently encourage participation from students who are reluctant to speak. I like to do this about half way through the seminar with a gentle encouragement like, "My next question is for people who have not yet participated today." Or I might say something like, "Let's hear a response from this section of the circle." Another technique I employ is to say, "Before we hear this in group let's all turn to the person next to us and share our ideas first." Then I say, "Now let's hear from someone who has not spoken yet." This is a good technique because some of your shyer students will feel more comfortable speaking after they have first tried it out on the smaller audience of their partner, and some students who have not come up with any ideas to share can borrow from what they heard their partner say.

Seminar works best with groups for 12 to 15 students. Clearly most classrooms are larger than this. My favorite way to overcome this obstacle is to split my class in half and send one half with another staff member to seminar. I have used assistants, literacy facilitators, talent development teachers, parent volunteers, and even the principal to hold seminar with the other half of my class. If human resources are scarce in your school you can have an outer circle and an inner circle. The outer circle maps responses while the inner circle participates in the seminar. Half way through the seminar the groups switch places and roles. I do not like this technique as well as it eliminates students from participation in half of the questions. A slightly better solution is to partner someone on the outer ring with someone on the inner ring. They discuss the questions first and then the question is opened to the entire group to seminar in the inner ring. This does increase the number of students answering each question so I like it better. As with the last technique, students switch from the outer ring to the inner ring half way through seminar.

Seminar Sources

To help you get started I have listed a few sources that are good for selecting seminar pieces from.

Touchstones

This is a program that is best known for its texts on moral dilemmas for students to consider. Less well known is a series by Touchstones called Where'd They Get That Idea by Howard Zeiderman that explores concepts in science and math such as How straight is straight or possible ways to classify geometric figures. The emphasis is on a logical approach to defining and exploring concepts in science and math. One benefit of this resource is that it gives a lesson plan design that suggests how to set up and run seminar. This is very helpful if you have not incorporated seminar in your teaching repertoire before and need some guidance on how to run a seminar.

Quotes

Another great source for seminar is famous quotes. The quotes can be centered around theme, a historical time period, or profession of the people quoted. You may also use a selection of quotes with no specific connection and have students organize them by categories they create themselves. I have included a seminar I created from a selection of quotations to give you an idea of what it might look like and questions that can be asked in seminar in general. You will notice one quote from someone you have probably never heard of, Remy Lucien. Remy is my son and he likes to write poetry. Although a year above the class I originally used this quote with all the students in the room knew Remy. I included a quote from one of his poems to demonstrate to my students that you do not have to be famous to have important things to share. After all, I am trying to get them to share important things in seminar themselves. For this purpose Remy stood as an example of a peer. For this to work in your class you would need to find a quote from someone they know.

Short Stories, Novel Excerpts, and Poetry

Texts for seminar should be selections that students can read in a single setting. Short stories are a good source to use. Some of my favorite short stories for seminar are Ray Bradbury's *All Summer in a Day*, Leo Tolstoy's *Poor People*, and Shirley Jackson's *Charles*. Of course any short story you find intriguing and ambiguous in interpretation will work. If you do not have a good idea of where to start in finding short stories there are a few series that are a good place to start. Jr. Great Books have good selections and have series for a variety of grade levels. The College of William and Mary has put together a curriculum for students identified in the Talent Development program (formerly called AG for Academically Gifted), called *Autobiographies: A Language Arts Unit for High Ability Learners Grades 5-6*. All of the short stories suggested above can be found in this resource.. When we do a novel study I often pull a single chapter or scene to discuss in seminar. In many novels authors select a poem or quote to begin particular chapters and these can be good seminar texts as well. Mildred Taylor has a poem at the beginning of chapter 11 in her novel *Roll of Thunder Hear My Cry* that is excellent for seminar. Of course, poetry in general is a good seminar selection. I am sure you can remember a number of poets like Frost or Melville that you read when you were in school, but look for more modern pieces as well. Marge Piercy's poem "To Be of Use" is an excellent seminar poem I picked up from the book *Teaching with Fire: Poetry That Sustains the Courage to Teach* edited by Sam M Intrator and Megan Scribner. For more traditional texts from philosophers you can use the *Philosophy for Kids* and *The Examined Life: Advanced Philosophy for Kids* by David White. This series of books includes essays and excerpts from everyone from Socrates to Sartre. Besides giving seminar texts White also gives ideas on how to integrate the pieces into other areas of the curriculum enriching the experience of the selection.

Propaganda

Another text I just recently found is *Crimes Against Logic* by Jamie Whyte. In the very first chapter of this book Whyte argues against a right most of your students will staunchly believe they have; the right to your own opinion. After reading Whyte's argument students will recognize that the invocation of this right is often used to support what is actually an illogical argument. It will also give them pause to consider whether they truly have this right or not. The rest of the book also points out when people are arguing in a way that defies logic and how to recognize these flaws in others' arguments. This book is a great tool for teaching students to identify propaganda and each chapter could be done as a seminar.

Culminating assignment

As a culminating activity we will learn about nuclear energy. With the need for alternative energy sources and the recent disaster at the Fukushima Nuclear Plant in Japan this is a timely topic that has no clear correct side. I will use texts and video and hopefully experts to represent both sides of the argument. After this I will have students seminar on the issue and then write about it. There writing will reflect more than just what side they are on and why. What I really want to know is the process they went through to get to their decision. Are they choosing a side because their parents hold that belief? Was there an argument in the one of the sources we reviewed that they found more convincing? How did they judge what arguments were most sound and valid? How did they weigh the costs and risks of nuclear energy against the benefits? Were they able to put aside their Optimism Bias, or do they think such a disaster could never happen here? I feel very comfortable with this topic for my students because I am not sure where I stand on it. This is exactly the type of issue I am looking for so that we can explore it as learners together. The whole activity will be a moot point if they return to their natural tendency to simply look to me or a parent to parrot our belief.

Examples

Matrix

Here is a copy right free matrix my son, Remy, and I created.

There are five children in the Lucien family. There are two sons named Christopher and Remy, and three daughters named Emily, Janice, and Sherri. On weekends the family goes out to dinner, but on Monday through Friday a different child is responsible for preparing dinner. Each child makes a particular meal: fried chicken, chili, pizza, pasta, or tacos. From the information given, determine the night of the week each person makes dinner and the meal they prepare.

1. Christopher's night of the week comes before his sister who makes pasta but after his sister who makes chili.

2. Remy's night comes before Emily's night but after his sister who makes tacos.

3. Emily does not make pasta and neither does Janice.

4. Remy does not make fried chicken.

Answer key:

Remy: Tuesday: Pizza
Emily: Wednesday: Chili
Janice: Monday: Tacos
Sherri: Friday: Pasta
Christopher: Thursday: Fried Chicken

	Remy	Emily	Janice	Sherri	Christopher	Fried Chicken	Chili	Pizza	Pasta	Tacos
Monday										
Tuesday										
Wednesday										
Thursday										
Friday										
Fried Chicken										
Chili										
Pizza										
Pasta										
Tacos										

Seminar on Quotations

These quotes are the text I use for my quotation seminar. I introduced one quote a day for ten days. In a journal they copied the quote, made sure they understood all the words used in the quote, wrote their interpretation of the quote and illustrated it.

Remember always that you have not only the right to be an individual; you have an obligation to be one. You cannot make any useful contribution in life unless you do this.

Eleanor Roosevelt

Injustice anywhere is a threat to justice everywhere.

Martin Luther King Jr.

Not until the creation and maintenance of decent conditions of life for all men are recognized and accepted as a common obligation of all men...shall we...be able to speak of mankind as civilized.

Albert Einstein

Man is condemned to be free; because once thrown into the world, he is responsible for everything he does.

Jean-Paul Sartre

When you reread a classic you do not see more in the book than you did before; you see more in you than there was before.

Clifton Fadiman

Conscience is the inner voice that warns us somebody may be looking.

H.L. Mencken

Some men see things as they are and say, why. I dream things that never were and say, why not.

Robert F. Kennedy

The reason why worry kills more people than work is that more people worry than work.

Robert Frost

Lost in the woods,
Forever searching for a path to follow,
But it is only when we realize
We must forge our own path
That we will find our way.

Remy Lucien

If you do not tell the truth about yourself, you cannot tell it about other people.

Virginia Woolf

This is the seminar format I use for designing pre and post seminar activities, as well as a guideline for the questions I will ask during seminar.

Text Title: *Quotes*
Ideas values: Courage, Justice and Fairness, Society, The Individual

Pre-Seminar

Content: Copy and interpret each quote into a quote journal.

Seminar

Opening: (global question, main idea, or theme related)

1. Which quote was the most difficult to understand?
(Encourage them to help each other understand the quotes)

Core Questions: (text specific questions)

1. What common themes do you see in these quotes?
2. Which of these quotes have more to do with the individual and which have more to do with society?
3. Do you see any similarities between the people who generated these quotes?
4. If all writing was going to be destroyed and you could only keep one quote to share with future generations which one would you choose and why?
5. What important aspects of life are not addressed in any of these quotes?

Closing Questions: (personal connection to the text)

1. Which quote is most applicable to your life and why?

Post-Seminar

Content:

1. Think of a message you think people or society needs to hear. Write a quote that conveys your message.

Notes

1. Bennett, *Logic Made Easy*, 17
2. Finocchiaro, "Psychological Explanation of Reasoning," 280
3. Shermer, *The Believing Brain*, 62
4. Sharot, "The Optimism Bias," 66
5. Oz, "What I Learned From," 51

Resources

Baska, Joyce, Dana T. Johnson, Linda Neal Boyce, Chwee Quek, Claire Hughes, Catherine A. Little, and Michael Clay Thompson. *Autobiographies: A Language Arts Unit for High-Ability Learners, Grades 5-6*. Dubuque, Iowa: Kendall/Hunt, 1998. This is a good source for seminar texts for upper elementary and middle school students. It also has critical thinking activities.

Childs, Leigh. *Nimble With Numbers: Engaging Math Experiences to Enhance Number Sense and Promote Practice*. White Plains, N.Y.: Dale Seymour Publications,

2000. This is a great source for logic problems in math for fifth and sixth grade or students working at that level.

Fisher, Alec. *The Logic of Real Arguments*. Cambridge [England: Cambridge University Press, 1988. This book is a good resource for teachers to improve their own use of logic. It can also be used with students in middle grades, or students reading on a sixth grade level or higher.

Fisher, Alec. *Critical Thinking: An Introduction*. Cambridge, U.K.: Cambridge University Press, 2001. This book is a good resource for teachers to improve their own critical thinking. It can also be used with students in middle grades, or students reading on a sixth grade level or higher.

Horner, Chris, and Emrys Westacott. *Thinking Through Philosophy: An Introduction*. Cambridge, UK: Cambridge University Press, 2000. This book is a good resource for introducing philosophy. It can be used with students in middle grades, or students reading on a sixth grade level or higher.

Intrator, Sam M., and Megan Scribner. *Teaching With Fire: Poetry That Sustains the Courage to Teach*. San Francisco: Jossey-Bass, 2003. This book is a pleasure to read and a good source of poetry for seminar or other teaching activities.

"Math Olympiads for Elementary and Middle Schools." Math Olympiads for Elementary and Middle Schools. http://www.moems.org/ (accessed November 23, 2011). You can go here to order resources for Math Olympiad.

Post, Beverly, and Sandra Eads. *Logic Anyone?: 165 Brain-Stretching Logic Problems*. Belmont, Calif.: Fearon Teacher Aids, 1982. This source provides analogies, matrices, syllogisms, and more.

"Sudoku Tutorial." Logic Games Online - Play Games In Your Browser. http://www.logicgamesonline.com/sudoku/tutorial.html (accessed November 23, 2011). Use this source to better understand the logic used in solving Sudoku puzzles.

Taylor, Mildred D.. *Roll of Thunder, Hear My Cry*. New York: Dial Press, 1976. This novel brings up many issues for discussion in class.

White, David A.. *Philosophy for Kids: 40 Fun Questions That Help You Wonder ... About Everything!*. Waco, Tex.: Prufrock Press, 2001. This is a good source for seminar text and higher level thinking activities.

White, David A.. *The Examined Life: Advanced Philosophy for Kids*. Waco, Tex.: Prufrock Press, 2005. This is a good resource for teaching students philosophy or for choosing seminar texts.

Whyte, Jamie. *Crimes Against Logic: Exposing the Bogus Arguments of Politicians, Priests, Journalists, and Other Serial Offenders*. New York: McGraw-Hill, 2005. This is a good teacher resource for learning more about detecting illogical arguments. It is also a good resource to use with advanced readers for teaching propaganda and possible seminar texts.

Zeiderman, Howard. *Where'd They Get That Idea? Issues and Ideas in Science and Mathematics*. Annapolis, MD: Touchstones Discussion Project, 1998. This book provides good seminar texts for topics in science and math.

Works Cited

Adler, Mortimer. "What is an Idea?." *The Saturday Review*, November 22, 1958. Mortimer Adler was a leader in the formation of the Paideia approach to teaching.

Bennett, Deborah J.. *Logic Made Easy: How to Know When Language Deceives You*. New York: W.W. Norton & Co., 2004. Logic Made Easy is a good reference book for teachers looking to increase their own skills in logic. Written in an easy to understand and entertaining way.

Doyle, Sir Arthur Conan. *The Complete Sherlock Holmes*. Garden City, New York: Doubleday, Doran & Company, Inc, 1905. Good fictional reference for the art of deduction.

Maurice A, Finocchiaro. "The Psychological Explanation of Reasoning: Logical and Methodological Problems." *Philosophy of the Social Sciences* September, no. 9 (1979): 277-292. This article describes problems people encounter when trying to solve logical puzzles and problems. It also gives methods for overcoming them.

Oz, Mehmet. "What I Learned From My Cancer Scare." *Time*, June 13, 2011. This article shows how the optimism bias and other emotional factors weigh in our decision making processes.

Politzer, Guy. "Differences in Interpretation of Implication." *American Journal of Psychology* 3, no. 94 (1981): 461-477. Politzer argues that the use of visuals increases a person's ability to solve logic problems.

Sharot, Tali. "The Optimism Bias." *Time*, May 28, 2011. This source explains how memory and decision making are affected by an evolutionary predilection towards optimism.

Shermer, Michael. *The Believing Brain: From Ghosts and Gods to Politics and Conspiracies--How We Construct Beliefs and Reinforce Them as Truths*. New York: Times Books, 2011. This source explains how beliefs are difficult to override even in the face of logical evidence.

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Appendix A: Implementing District Standards

North Carolina Standard course of study: Language Arts- Grade 5

2.09 Listen actively and critically by asking questions, delving deeper into the topic, elaborating on the information and ideas presented, evaluating information and ideas, making inferences and drawing conclusions, and making judgments.

This goal is about thinking critically about ideas presented. Many of the activities in the unit promote this type of thinking, especially the seminars, matrices, and other activities where students are required to listen to the ideas of their peers and judge their validity.

North Carolina Standard course of study: Math- Grade 5

1.03 Develop flexibility in solving problems by selecting strategies.

Multiple puzzles and techniques are explored to build a students use of logic in selecting and implementing problem solving strategies.

North Carolina Standard course of study: Science- Grade 5

1.06 Explain and evaluate some ways that humans affect ecosystems.

The culminating activity has students evaluating the pros and cons of nuclear energy.