Integrating Scientific Method & Critical Thinking in Classroom Debates on Environmental Issues

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Integrating Scientific Method & Critical Thinking in Classroom Debates on Environmental Issues

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Biology teaching should provide students with the knowledge and skills to deal with current environmental issues that are often a complex mix of social, economic, political, and ecological aspects. Classroom debates about environmental issues are ideal to develop knowledge; they expose students to a variety of contradictory, sometimes extreme perspectives, and allow them to increase their scientific literacy. Zipko (1991) used such debates in grades 7-12 to make his biology students realize that the solutions to environmental problems are controversial. Through various strategies such as collaborative learning (Anderson,1998) or cooperative controversy (Hammrich & Blouch, 1998), students can compare and analyze arguments, and reach higher levels of understanding. Debates allow students to increase their participation; acquire interpersonal and oral communication skills; and develop a better understanding of the issues at hand. For students to acquire such skills and understanding, it is insufficient to provide them with a list of suggested debate topics and set the stage with opposing teams. In order to conduct successful debates, it is necessary to prepare students to integrate scientific method and critical thinking.

Scientific Method

Scientific method is a stepwise circular process (Ratti & Garton, 1994):

1. It begins with some observations that are synthesized into a theory.
2. The theory is stated explicitly in the form of hypotheses, which are predictions of outcomes.
3. The predictions are tested through experimentation or observation.
4. The theory is modified or expanded on the basis of the results of these tests. Scientific method accepts no knowledge as completely fixed or infallible, and its stepwise process continuously challenges new theories.

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From kindergarten to grade 12, students learn about scientific method. However, from one grade to the other, they may not establish the logical connection existing between the various steps. Starting with kindergarten, it is important to introduce students to the overall concept of scientific method. Even though the students are too young to fully understand all the steps of the method, they must become familiar with terminology. Every time students learn more about one step, they must know where it is located within the whole process. They must understand that scientific method is a valuable process only if all its steps are properly implemented.

Facts & Theory

The raw materials of scientific method are facts, i.e., the real state of things (Storer et al., 1972). Facts are gathered through careful observations, descriptions, and records. Facts are used to develop theories. A theory is a general conjecture that explains the observed facts (Romesburg, 1981).

Hypotheses

Hypotheses are predictions based on the proposed theory. They are working explanations that are submitted for testing.

Experimentation

Experiments are used to test the validity of hypotheses. Experimentation involves specific procedures to collect data and avoid biases when ascertaining the truth or falsity of a hypothesis.

Conclusion

Test results and analyses allow scientists to make conclusions on the validity of their hypotheses. This deductive process leads to generalizations about a particular subject. However, no theory in science is ever absolutely and finally proven (Keeton, 1972).

Example

Repeated observations (**facts**) on muskrat (*Ondatra zibethicus*) distribution led to the generalization (**theory**) that muskrats inhabit all aquatic ecosystems (Perry, 1982). Proulx and Gilbert (1983) predicted (**hypothesis**) that the distribution of muskrats depended on the simultaneous presence of water and vegetation. Their study (**test**) consisted of capturing and monitoring muskrat when water levels were low (i.e., less than 15 cm deep, with vegetation beds that were almost dry) and high (i.e., more than 15 cm of water, with plants surrounded by water). They observed (**data**) muskrat houses and animal captures only in areas where at least 15 cm of water was interspersed with emergent vegetation. They did not find houses in aquatic areas without vegetation. On the basis of their data analyses, they **concluded** that both water and vegetation had an effect on muskrat distribution.

Critical Thinking

Students involved in environmental debates have opinions of their own, and when they have deeply felt emotional underpinnings on a particular issue, they must deal with opposing viewpoints. Bender and Leone (1981) point out that "... to have a good grasp on your own viewpoint you must understand the arguments of those with whom you disagree. It is said that those who do not completely understand their adversary's point of view do not fully understand their own." Opposing viewpoints may confuse students if they are not familiar with critical thinking, a process that consists of carefully determining whether to accept, reject, or suspend judgment about what someone says. Critical thinking is a stepwise process to analyze, test, and evaluate arguments (Barry, 1992). Some of the skills of critical thinking include:

1. Identifying the argument's main idea
2. Evaluating sources of information
3. Evaluating the evidence
4. Evaluating the claim.

What Is the Argument's Main Idea?

The **main idea** is the key claim that a debater makes amidst all the claims that make up the opposing viewpoint. If one misses the debater's main idea or conclusion, one cannot:

1. Identify evidence
2. Evaluate how well the evidence supports the main idea
3. Determine whether or not the arguer's reasoning is good (Barry, 1992).

A main idea may be missed simply because the arguer's presentation is ambiguous or vague.

Making sense of what someone says calls for a close inspection of the physical context of the message. Students must therefore develop their listening skills, and examine the linguistic context–signal words, syntax, and punctuation. Certain words and phrases usually signal the presence of an argument and simultaneously distinguish premises and conclusions: *therefore, hence, so, accordingly, thus, consequently,* etc. Johnson and Blair

(1977) recommend the following procedure to extract the bare bones of an argument from its rhetorical dressing:

1. Look for and focus on the argument.
2. Set aside phrases, sentences, and even paragraphs that are extraneous to the bare argument.
3. Separate each statement that belongs to the argument as a distinct premise (or conclusion).
4. Reformulate the premises and conclusion(s) necessary in order to have all the points stated in straightforward and clear language.
5. Double-check to make sure that no changes you make alter the meaning.

In the end, making sense of what someone is saying calls for reflection and deliberation that ultimately leads to a decision about which of several interpretations is the most plausible, given the physical and linguistic environment of the message (Barry, 1992).

For example, in a school debate about the status of wolves in a given state, a student may advance the following:

> *Currently, many newspaper articles focus on environmental issues. They all suggest that today's wolf populations are disappearing due to human persecution. Under pressure from ranchers and oil companies, politicians are so misinformed that they are oblivious to naturalists' concerns about the absence of wolf packs. Our forests are harvested, and climatic conditions are changing. Politicians do not understand enough about our environment to stop wolf-culling campaigns. Although biologists recognize that wolf densities are decreasing, they offer no solution to resolve the problem. Consequently, it is unlikely that we will see any wolves in the near future.*

The main idea is that wolf populations are decreasing in numbers. Key statements are *wolf populations are disappearing, absence of wolf packs, wolf culling,* and *wolf densities are decreasing.* The last sentence of the statement is the student's conclusion, which relates to this main idea. References to politicians' shortcomings, biologists' lack of solution, and changing environments may be the cause of the wolf misfortune; however, they are not main arguments.

How Valuable Is the Source of Information?

Environmental issues are investigated by scientists, and they are sometimes vulgarized by journalists. When listening to a debater's point of view, one must question the source of information. Students must therefore be taught the difference between popular and refereed publications.

Ford (1998) pointed out that, "The primary sources of scientific information for the average citizen are newspapers, magazines, television, radio and the internet. Many times the claims lack supporting scientific evidence, are presented by biased sources, or are the product of faulty logic." On the other hand, information about environmental issues may be sought in refereed journals, i.e., publications with peer-reviewed articles. Scientists reviewing the content of scientific articles must assess the adequacy of the research protocols used to investigate the issue at hand; they must determine if the authors' conclusions are substantiated by their findings. The reviewers must ensure that scientific method has been properly used to generate scientifically sound facts. Pall (2000) described a course where students were required to review a popular article and a scientific paper on the same subject. He pointed out that students need to be taught how to recognize a peer-reviewed article. They need to distinguish between primary literature and a review article; they must learn how to read a scientific paper while bypassing some of its statistical complexity. Recognizing the value of the source of information is a vital step in assessing opposing viewpoints.

Evaluating the Evidence

The premises of an argument must provide sufficient evidence for the conclusion. Knowing how to evaluate evidence is the most important step of a debate. It requires that a student differentiate between a factual statement (which can be demonstrated or verified empirically), and an opinion (a belief or an attitude that cannot be proven). It requires that the student distinguish between reason (a conclusion that can be clearly and logically explained or justified), and prejudice (a preconceived judgment based on feelings instead of reason) (Bender, & Leone, 1981).

Ford (1998) recommends that students list all the evidence presented by the arguer(s) that is related to the main idea. Sometimes debaters will include "evidence" that contradicts or indirectly supports the main claim. This evidence must be listed and assessed to adequately evaluate the primary idea. The students must first assess its relevance to the argument, and then determine how effective it is. It is at this level of critical thinking that students must verify if the arguer is using information generated through scientific method to substantiate the main idea. Science does not make value or moral judgments. "Science rests upon the conviction that all events of the universe can be described by physical theories and laws, and that such data can be gathered through our senses. These laws do not say how things should be; they say how things are and probably will be" (Keeton, 1972). One must therefore carefully examine the data presented and the methods used to obtain it. In a debate, arguers should be prepared to submit copies of their sources for review. Is the argument based on dubious assumptions? Does the data support the arguer's claim? Is the sample size biased or too small? Is the information generated from a biased source? Is the conclusion substantiated by evidence? What are the alternative interpretations, and on what basis did the arguer reject them?

Evaluating the Claim

Once the evidence has been thoroughly evaluated, one can accept or reject the argument. If the listener rejects an arguer's point of view, it is important that the reasons for such a decision be clearly stated. Was the argument improperly substantiated? Was the conclusion oversimplified?

If the opposite viewpoint is found valid, there is no point in continuing to argue the issue at hand. Otherwise, the whole exercise lacks purpose. The claim may be accepted as a whole or in part, depending on its complexity. However, reasons for acceptance of the claim should also be disclosed.

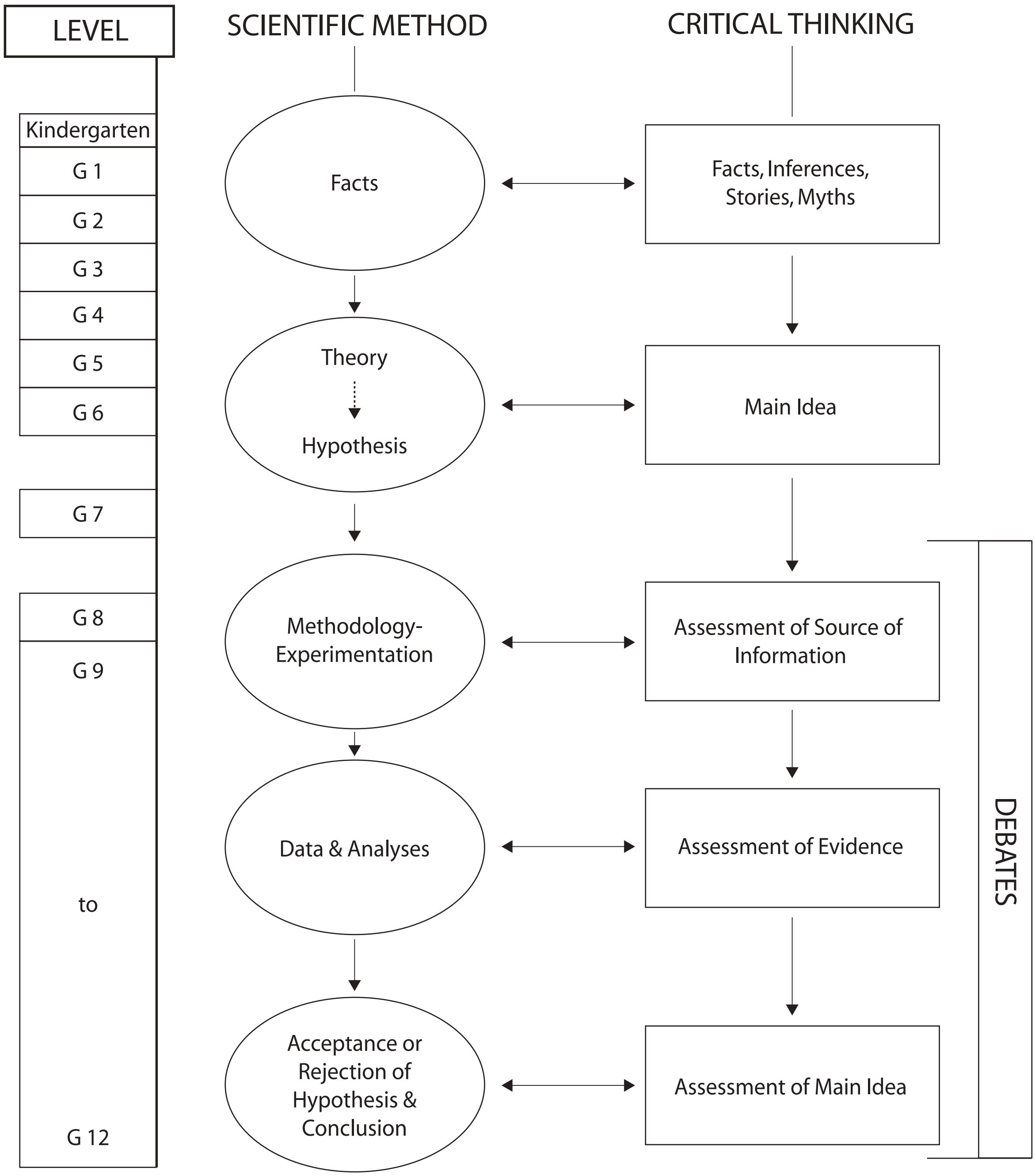
An "Experimental" Course

I am a scientist involved with various controversial issues such as trapping, deforestation, and animal control in agriculture. I believe that integrating scientific method and critical thinking is essential in making a point, and in evaluating the opinion of others. To test my claim, I gave a course at the Faculty of Extension of the University of Alberta entitled *"People and Animals: Ethics, Rights and Responsibilities."* The course was attended by six professionals associated with college and university agriculture departments, one representative of pork producers, one representative from a pharmaceutical drug company, and two individuals from the public at large, self-described as animal "welfarists."

On Day 1 of the course, students were introduced to critical thinking and scientific method. The individual representing the pork industry was absent. During review of animal welfare and animal use issues, it was pointed out that these processes can be used to better analyze different viewpoints. For example, when presenting the pros and cons of controversial issues such as fur trapping, filmed debates were shown of people arguing about cruelty and the use of furs in today's society. These pointed out how debaters from both sides of the issue failed to use critical thinking during the debate.

On Day 2, a speaker (a high school teacher belonging to an animal rights group) was presented to students. She gave a talk about human-animal relationships. She made a series of consecutive claims about agriculture's "fouling" environment, "unhealthful" dairy products, the "cruelty" of having pets, and the "unnecessity"of using animals in medical research. She made several attacks on industries with which many of the students were associated. However, most of the class remained calm. At the end of the individual's presentation, students methodically asked a series of questions by using scientific method and critical thinking to assess the claims. Students who had been introduced to scientific method and to critical thinking on the first day remained professional in their evaluation of the arguer's viewpoint.

Figure 1.
Relationships between class levels, teaching of scientific method and critical thinking, and integration of debates.



The student who had missed the first day of the course became very emotional, shouted at the speaker, and also delivered a series of claims. The animal activist's counterarguments consisted again of a series of statements such as "cattle production is the primary contributing factor in all causes of desertification," "the pork industry gets rich, and you get fat," and "animal research retards medical progress." During the first presentation and during the reply, the arguer did not present scientific studies published in peer-reviewed journals. On the other hand, most students were able to refer to some basic published work on animal welfare indicators and could relate to personal observations in their field of expertise.

The presentation was followed by a workshop where students evaluated the speaker. Most students rejected the speaker's arguments. Their analysis of the evidence indicated that the speaker failed to define welfare criteria. They felt that allegations were based on opinions rather than facts, and that many premises were out of context. One of the students who considered herself an animal welfare activist refused to evaluate the speaker's opinion with critical thinking. The student believed that the animal activist presented basic human emotions that cannot be assessed with a stepwise technique. She considered that all the students and the instructor were biased.

The overall class evaluation of this "experimental" course was that the concept of critical thinking and the firsthand presentation from an animal rights representative were excellent learning experiences. The course opened up their minds by using critical thinking to judge different views.

I do not believe that unanimity can be reached when dealing with controversial environmental issues. People differ on the basis of their beliefs, academic formation, and work ethics. For example, many studies have demonstrated that gender, age, and occupation have a definite influence on attitudes towards animals (Kellert & Berry, 1987; Czech et al., 2001). Some segments of the public are more utilitarian than others, and view animal-use differently from animal rights groups or uninterested members of our society (Bright et al., 2000).

The class was dominated by students involved in animal-use industries, and their reactions toward the animal activist's point of view were predictable. The majority of students still used a step-by-step approach when assessing the speaker's claims. The simple fact that the majority of students were able to remain calm during the presentation, and articulate and rationalize their point of view, was a noticeable change from the usual shouting matches observed in public debates on environmental issues. My own assessment of the course was that it is advantageous to use scientific method and critical thinking when debating environmental issues.

Integrating Scientific Method & Critical Thinking in K-12 Curricula

Teaching scientific method and critical thinking to K-12 students must take into account their scientific intellectual development. It would be ludicrous to expect grade 1 students to understand the consequences of global warming on the future of boreal forest wildlife communities. These students have not acquired the basic knowledge about animal populations and ecological relationships to assess factual information and carry out deductive reasoning.

Scientific method is based on facts; critical thinking, on evidence. Students must learn about facts, and recognize them from stories and inferences, throughout their pre-university schooling. From kindergarten to grade 5, curricula should focus on facts, i.e., repetitive observations, data variations, and record keeping. In grade 5, students who have been properly trained to record facts will likely be able to predict outcomes and

Table 1.
Examples of environmental debate topics with reference material.

SUBJECT	VULGARIZED ARTICLES	PEER-REVIEWED ARTICLES
Deforestation	McLaren (1990) Montaigne (2002)	Keenan and Kimmins (1993) Youngblood and Titus (1996) Angelstam, et al. (1997)
Game ranching	Struzik (1987, 1991)	Geist (1985) Milne and Reid (1989) Bothma and Teer (1995) Hudson (1995)
Genetically modified food	Ackerman (2002)	Hohn and Leisinger (1999) Dale, et al. (2002)

develop testable questions. Also, from grades 6 to 8, students should learn about theories, hypotheses, and stepwise investigations. Curricula should then focus on establishing logical connections among theory, hypotheses, tests, data, and conclusions. Students entering grade 9 should have a good understanding of scientific method.

Critical thinking is a stepwise process consisting of elements very similar to those of scientific method (Figure 1). Students should learn progressively about this process while discovering scientific method. By the end of grade 8, students should recognize the similarities existing between these two processes. They should be able to identify a main idea, evaluate evidence, and reassess the main idea.

From grades 6 to 8, curricula consist largely of conventional (passive) learning, science classes (including some team work), and supervised experiments. These may not be enough to produce students with skillful scientific judgment. Debates are an opportunity to help students establish links between elements of scientific method that they learned over the years, and to develop critical thinking through firsthand involvement.

Environmental Debates at the Secondary Level

Zipko (1991) showed that it was possible to initiate debates as early as grade 7. This is ideal if curricula allow it. If time is a constraint, debates are easier to conduct starting in grades 9 to 12, when students benefit from greater independence in the preparation of their classes. High school curricula also provide students with guided experimentations where students can further develop their understanding of scientific method (including scientific writing), which will help them in preparing debates.

It is not my intention to describe all the steps of a debate. Zipko (1991) made valuable recommendations on how to carry out and evaluate such debates. However, two steps are mandatory. Teachers must: 1) review scientific method and critical thinking processes at the beginning of each year, even at the high school level; and 2) strategically select subjects and materials that will allow students to develop critical scientific minds.

Reviewing scientific and critical thinking processes should be done according to Figure 1. By strategically selecting debate subjects, teachers may avoid sparring matches without substance. Subject selection allows teachers to further improve on the content of their curriculum. More important, by selecting and researching debate topics, teachers develop some knowledge of pros and cons, and can establish criteria to assess students' performances. While reviewing debate topics, teachers can develop a small library that students will consult to evaluate issues at hand, and identify their own viewpoints.

Environmental debates should deal with topics for which there are ample popular and scientific documentation. Debates should be about the real world, not about speculations. For example, a debate about protecting alien life on Mars is useless since such life has yet to be found. Zipko (1991) listed a series of subjects that are compatible with environmental debates. In the last decade, new issues and concerns (e.g., cloning, genetic engineering) have been identified, and should be considered as possible subjects. Table 1 provides the reader with examples of debate topics, and corresponding popular and peer-reviewed articles.

Conclusion

Ensuring continuity in the teaching of scientific method and critical thinking from Kindergarten to Grade 12 will require that teachers truly harmonize their curricula. Teachers will also have to take extra time to prepare environmental debates, and incorporate them in their regular curriculum. All this effort will foster critical thinking among classrooms, and produce students with critical, scientific minds. As Romesburg (1991) pointed out, "... our curricula should foster thinking first, including as a byproduct the important items to be memorized."

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