Fallacies and Student Discourse: Conceptualizing the Role of Critical Thinking in Science Education

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INTRODUCTION

It is revealing that the National Council for Project 2061 expresses a need for scientific literacy in the following manner:

> Scientific habits of mind can help people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems. (AAAS, 1989, p. 13)

This viewpoint reaffirms what already has become a recognized trend among many science educators. The pressing importance of engaging students in discussions of societal issues has been well documented in the science education literature over

Science Education 76(4): 437–450 (1992)

CCC 0036-8326/92/040437-14$04.00

the last decade. Several alternative approaches to conceptualizing classroom strategies involving student discourse on societal issues have evolved as well. Fleming (1986) stresses the normative contribution of social cognition as an independent convention playing a personal role in the adolescent's socio-scientific reasoning. Zeidler (1984, 1985, 1992; Zeidler and Schafer, 1984) emphasizes the cognitive and moral developmental interrelations that influence students' reasoning on moral and ethical issues in science, and how particular normative experiences mediate their judgments on such issues. Iozzi (1987) has developed a socio-scientific reasoning model that incorporates logical reasoning, social role-taking, and socio-moral reasoning with STS content knowledge.

The common thread that ties these approaches together is the emphasis on student argumentation and discourse. All require students to critically analyze the merits of their own reasoning and that of others when confronted with various socio-scientific dilemmas, scenarios, or problems. If we accept the notion that scientific literacy includes, in part, habits of mind in the sense conveyed by AAAS, then it seems appropriate to clarify the role of critical thinking in science education. This article will seek to examine that role by reviewing the following pertinent areas: Defining and Conceptualizing Critical Thinking; Common Fallacies in Student Argumentation; Implications for Science Education.

DEFINING AND CONCEPTUALIZING CRITICAL THINKING

Unfortunately, as our information data base expands in the educational and psychological literature, the meaning of various concepts becomes more obscured and unclear. The concept "critical thinking" has also suffered from this fate. Critical thinking is sometimes generically used as an umberella term to include all thinking operations, or sometimes equated with "problem solving" or Bloom's taxonomy when all such terms are in fact quite distinct. If it is true that hindsight is often 20/20, then perhaps revisiting Dewey's progressive notion of reflective thought may add clarity to our current understanding of critical thinking.

For Dewey, reflective thought entails: "Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends" (1933, p. 9). While many contemporary educators disagree on the nature of critical thinking (i.e., domain-specific versus generic reasoning skills), most appear to be in consensus that critical thought involves the *evaluation* of the worth, accuracy, or authenticity of various propositions (Beyer, 1988; Ennis, 1989; McPeck, 1981; Toulmin, Rieke, and Janik, 1984). Furthermore, this restatement of Dewey's main contentions also entails having the predisposition or inclination to consider questions that arise by way of healthy (but not frivolous) skepticism. There are two noteworthy points here central to Dewey's notion of reflective thought. First, a critical thinker possesses a certain mind-set with which he or she approaches ideas. "One can think reflectively only when one is willing to endure suspense and to undergo the trouble of searching" (Dewey, 1933, p. 16). Second, by definition, the critical thinker is a skeptic, that is, one who is unwilling to accept any assertion or idea until or unless evidence can be demonstrated sufficient to warrant its acceptance. Such reflective skepticism reveals itself when one is willing to sustain a protracted state of doubt that may be aimed at any assertion or idea that is presented for acceptance by anyone (including oneself).

Admittedly, it is difficult to avoid jargon, especially when discussing such a fruitful concept as critical thinking. The trouble, of course, is that particular terms may have general to quite specific connotations depending upon one's educational, psychological, and philosophical background. Hence, one may find critical thinking under the rubric of "aspects," "skills," "abilities," "attitudes," or "problem solving" (D'Angelo, 1971; Ennis, 1962; Frederiksen, 1984). Beyer (1988) offers one of the clearest and most robust conceptualizations of critical thinking and examines it as one kind (and level) of cognitive process. Beyer agrees that critical thinking requires a certain mind-set that is essentially evaluative in nature, but distinguishes critical thinking from "micro thinking skills" such as Bloom's taxonomy and those typically taught in logic and philosophy (inductive, deductive, and analogical reasoning). Beyer makes the case that such micro skills are rather discrete, simple reasoning tasks. It is important to note that simple reasoning tasks refer to following only a limited number of rules, steps, and procedures. Beyer also differentiates critical thinking from "thinking strategies" such as problem solving and decision making which are more complex cognitive processes aimed at the process of developing support to formulate a particular model or solution from what was initially a problematic situation or dilemma. Such thinking strategies consist of following a hierarchical sequence of subordinate procedures [e.g.: (a) recognize a problem; (b) represent the problem; (c) devise/choose solution plan; (d) execute the plan; (e) evaluate the solution] (Beyer, 1988, p. 57).

In contrast, critical thinking is conceptualized as a repertoire of specific operations, somewhere between major thinking strategies and micro thinking skills in their complexity and function. These critical thinking operations may be used *independently* or in *combination* and in *any order* (in contrast to the thinking strategies above or Bloom's taxonomy in which each level includes those antecedent to it). Beyer's conceptualization has broad utility in that those operations were derived and synthesized from the literature of science, language arts, and social studies instruction and are presented here from simple to complex (1988, p. 57):

- distinguishing between verifiable facts and value claims;
- distinguishing relevant from irrelevant information, claims, or reasons;
- determining the factual accuracy of a statement;
- determining the credibility of a source;
- identifying ambiguous claims or arguments;
- identifying unstated assumptions;
- detecting bias;
- identifying logical fallacies;
- recognizing logical inconsistencies in a line of reasoning;
- determining the strength of an argument or claim.

Thus, there exists a hierarchical nature among micro thinking skills, critical thinking operations, and macro thinking strategies (i.e., problem solving, decision making).

Critical thinking necessarily *includes* micro thinking skills and is understood to be a necessary condition for the adequate execution of problem solving strategies. The common criterion that critical thinking skills employ is that they all aim to separate "truths" from "falsehoods."

The most comprehensive use of critical thinking operations is perhaps best exemplified in the area of argumentation (Toulmin, Rieke, and Janik, 1984; Toulmin, 1958). When students are engaged in making assertions, supporting and defending those claims through a well-developed line of reasoning and judging the efficiency of counter arguments during discussions of socio-scientific issues, they will be making use of the operations identified above. Failure to adequately utilize those operations during discourse results in fallacious reasoning and flawed construction of personal epistemologies related to the issues at hand. An analysis of this problem is presented in the next section of this article.

COMMON FALLACIES IN STUDENT ARGUMENTATION

Although over the years science teachers become acutely aware that their students do not seem to think about ideas as they do, these teachers may not be aware that there exist definitive, systematic patterns of flawed reasoning behavior on the part of their students. While fallacies contained in arguments have always been of concern to philsophers, science educators have only recently taken notice of the importance of identifying difficulties in students' thinking skills. As classrooms move to engage in more verbal discourse in the form of argumentation among students, it is important to become better acquainted with certain fallacies common to student discourse.

A fallacy (or fallacious reasoning) is any argument that purports to be correct and is psychologically persuasive but that proves, upon scrutiny, to have violated some rule of logic which renders it incorrect. Fallacies have traditionally been distinguished as being either of a formal or informal nature; this distinction results from the different reasons why various fallacious arguments are psychologically persuasive despite their unacceptability. *Formal fallacies* are fallacious arguments that derive their psychological persuasiveness from their superficial resemblance to valid deductive argument forms. A valid deductive argument form is an argument form that is correct by virtue of its form alone, i.e., regardless of the content of the argument that takes its form. Syllogisms are perhaps the most common example of such argument forms. For example: "If predators are present, then the rodent population has decreased. The predators are present. Therefore, the rodent population has decreased." One of the most common fallacies of the deductive argument form is *affirming the consequent* and can be illustrated as: "If predators are present, then the rodent population has decreased. The rodent population has decreased. Therefore, predators are present." Notice the superficial resemblance between these two argument forms and their resulting conclusions. *Informal fallacies* are fallacious arguments that derive their psychological persuasiveness from their capacity to successfully deceive their victims due to either some sort of ambiguity in the language that is used to state the argument or some sort of device that is designed to illegitimately cause acceptance of the argument's conclusion.

Both in everyday life and in the academic setting, one is much more likely to encounter informal fallacies than formal ones. This is particularly true when students are engaged with interdisciplinary science topics that require a critical evaluation of socio-scientific topics that challenge other students' developmental structures and ethical norms. Accordingly, the focus of the remainder of this section will be on some of the most common informal fallacies prevalent in students' reasoning regardless of content area. However, this analysis does not mitigate the importance of specific subject or discipline knowledge on correct argumentation. On the contrary, the importance of domain-specific knowledge will be discussed within this section .

One convenient and fairly standard way to classify informal fallacies is to distinguish fallacies of relevance from fallacies of ambiguity (Copi, 1986). *Fallacies of relevance* are informally fallacious arguments that contain at least one premise that is logically irrelevant to its conclusion, thereby, rendering the argument incapable of establishing its conclusion as acceptable.

Some of the more frequently encountered fallacies of relevance are:

Ad hominem argument (argument to the man). Arguments that attack a person's character or credibility rather than the worth of that person's argument fall into this category. Specifically, one commits this fallacy whenever one attempts to cause the rejection of an opposing position either: (a) by attacking the proponent of that opposing position; or (b) by appealing to special circumstances or a special relationship that might exist between the proponent of the opposing position and some feature of the opposing position itself. *Examples:* (a) "David's objection to the nuclear power plant should be dismissed entirely, since he never knows what he is talking about." (b) Student: "I can not take your argument about abortion too seriously. After all, you are a girl and it is only natural that your arguments are going to be biased anyway."

Appeal to popularity. Students commit this fallacy whenever they deem acceptable or true a particular claim for no other reason than that most other people deem it acceptable or true, too. *Example:* "Evolution? Of course evolution is a proven theory! Everyone believes that; so, it hardly seems possible not to believe it."

False Dilemma. Students commit this fallacy whenever they base their argument on the assumption that there are only two possible options, when, in fact, there are more than two. *Example:* Student: "Well I guess if Darwin's theory of evolution is wrong on these issues, then the Creationist's view must be right."

Begging the question (circular reasoning). Students commit this fallacy whenever they include in the premises of an argument some form of the very same claim for which they are arguing. *Example:* A student defending her belief that a zygote is considered a "person": "A person's life begins at the moment of conception. All cells are living and a fetus is made up of living cells. So a person must exist at the moment of conception." Implicit in the premise that a person's life begins at the moment of conception is the assumed premise that a zygote is a person which, after all, is the exact same claim for which she is arguing.

Typically students with little understanding of argument structure will support a viewpoint without some proof or evidence. The literature contains examples across disciplines when students may unwittingly add information to the premises of their argument that is really part of their own conclusion. In such a case, the conclusion has now become part of the original premises. This faulty reasoning is apt to occur more often when the issues under consideration become more integrated and complex. The error stems from an inability to recognize that some type of independent support is necessary in order to advance particular claims (Cerbin, 1988; Nickerson, Perkins, and Smith, 1985; Toulmin, Rieke, and Janik, 1984).

Hasty generalization. Students commit this fallacy whenever they make or accept a generalization on the basis of a sample that is neither sufficiently large nor either representative or randomly selected. *Example:* A student who is collecting information on the spread of the AIDS virus offers the following line of reasoning: "I don't think our town should be spending tax dollars for AIDS research. Only two cases of AIDS were reported in our local paper last year and everyone I asked in our class is against it anyhow. These facts do not justify us spending money when much more money is needed for other health issues."

Inadequate sampling is often facilitated because what qualifies as acceptable evidence often differs across academic disciplines. Students, therefore, become unclear about what constitutes sufficient or appropriate evidence. As is quite often the case, students are apt to rely on personal experiences to advance claims even though they could strengthen their positions by pursuing further gathering of evidence appropriate to that discipline. Cerbin (1988) notes that higher education often produces students who are subjective and discipline-biased because instruction fails to make clear what counts as legitimate support for arguments in various disciplines (e.g., statistical data, examples, principles, theory, authority, interviews, historical evidence, etc.). Hence, students often view good arguments as arbitrary depending on the teacher's personal preferences inasmuch as those teachers may not clearly convey the epistemological expectations of the paradigm.

Other sampling practices that may result in hasty conclusions include the fact that students may seek too little information to warrant a firm conclusion. Conversely, students may seek to acquire voluminous amounts of information. The problem now lies in the fact that they unwittingly give equal weight to all studies or sources of information. Students also tend to overemphasize the frequency of rare events that contain inherent shock value but underestimate the occurrences of more common events. Another example of inadequate sampling is the failure of students to attend to either counter-evidence or confirming information. Finally, many students simply lack a functional understanding of probabilistic and statistical information. There is a strong tendency for students to disregard base-rate information in favor of intuitive causal judgments. Their reliance on heuristic approaches to obtaining support for a position often results in unrepresentative samples and limited hypotheses that may not leave room for competing hypotheses (Kahneman and Tversky, 1971, 1973; Kuhn, Amsel, and O'Loughlin 1988; Lichtenstein, Slovic, Fischhoff, Layman and Coombs, 1978; Nickerson, Perkins, and Smith, 1985;

Shweder, 1977; Snyder and Swann, 1978; Tversky and Kahneman, 1982; Wason, 1974; Well, Pollatsek, and Konold, 1981).

Appeal to authority. Students commit this fallacy whenever they appeal to a person who has expertise in one field, for advice or information in a field in which that person has no particular expertise. *Example:* A student uses the opinion of a renowned social scientist to add support to a claim as to the emotional stability of certain subjects after research had been conducted with them. The expert scientist, with no particular training in clinical psychology, draws inferences about the subjects' emotional stability. "The subjects, in my considered opinion, did not undergo any long term psychological damage as a result of this research."

While there exist many other fallacies of relevance (e.g., "the fallacy of two wrongs make a right," "the straw man fallacy," "the slippery slope fallacy"), the aforementioned describe some of the more frequently occurring examples of student argumentation. In general, any argument that contains an illegitimate emotional appeal as in appeals to pity, fear, hate, greed, flattery, peer pressure, etc. fall into the category of fallacies of relevance.

Fallacies of ambiguity. These are informally fallacious arguments that contain an ambiguous word or term the meaning of which renders the argument fallacious. Whenever a word or term can have either, but not both (or all), of two (or more) distinct senses in a certain context, the word or term is said to be ambiguous in that context. Typically, the ambiguous word or term requires one of its variable senses in order for the premises to appear to be acceptable while, simultaneously, requiring another of its variable senses in order for the conclusion to appear to follow from the premises. Any such shift in meaning is illegitimate and renders the argument fallacious. When an attempt is made to consolidate fallacies of ambiguity an unwieldy number begins to emerge. At last count, a review of the philosophical literature identified over 100 particular fallacies. However, the most frequently occurring fallacy of ambiguity that is likely to arise in classroom discourse is the following.

Fallacy of equivocation. The fallacy of equivocation is said to occur whenever there is an equivocation on a particular word or term the shift in meaning of which renders the argument in which it occurs fallacious. An equivocation is said to occur on a word or term whenever that word or term appears more than once in a particular context and purports to have a single meaning throughout that context but is used with different meanings in the different occurrences in that context. Consider a student who offers the following argument. *Example:* "Blacks and whites are historically, culturally and biologically different; the races are just not equal. Consequently, the laws have never meant that blacks and whites are equal in our society.

Superficially, this might sound like a plausible argument. However, any such plausiblity is attributable only to the student's use of the word "equal" twice and the possibility that the less than astute reader/listener might not detect the fact that in its initial occurrence "equal" must mean something like "identical" while in its second occurrence it has to mean something like "being entitled to the same rights." Thus to substitute the actual meaning of the word "equal" in their respective occurrences is to clearly demonstrate the argument's fallaciousness.

In addition to the common fallacies of informal arguments outlined above, there exist several other important factors which reside outside the realm of traditional philosophical identifications but nonetheless play a distinct role in mediating students' judgments about various socio-scientific issues. Three important considerations teachers may note for classroom discourse are described below:

Normative reasoning. Open-mindedness is a virtue that is held in high regard by many, but practiced by few. Typically, many students (particularly adolescents) exhibit forms of provincialism and are egocentric and ethnocentric in their reasoning. The ability to objectively comprehend, evaluate, and retain or reject the ideas of others is limited by their own group or societal viewpoint (Kurfiss, 1988). Such limited abilities would seem to arise from the fact that students tend to have more vested interests in their own arguments, or arguments of others which coincide with their own beliefs. Hence, many students will fall short of the ability to distinguish correct from incorrect reasoning because of social factors and vested interests which limit the open-mindedness necessary to evaluate compelling counter arguments. For example, Zeidler and Schafer (1984) have found that in trying to convince others of particular moral positions on socio-scientific issues, college students frequently referred to previous personal experiences and used those experiences to argue their point of view. This occurred with such regularity that their subjective experiences (such as social interactions with peer groups, parents, areas of interest) with various social norms played a constant role in mediating moral judgments on socio-scientific issues. There is much related evidence that demonstrated the extent to which normative social factors limit the ability to arrive at correct decisions (Nisbett and Wilson, 1977; Mahoney, 1977; Mahoney and DeMonbreum, 1977; Nickerson, Perkins, and Smith, 1985).

Naive conceptions of argument structure. There are errors evident in students' reasoning which arise from their lack of a conceptual framework about the structure of arguments. Perkins, Allen, and Hafner (1983) note that such students tend to rely on "makes-sense epistemology" (p. 185); that is, whether or not a proposition seems intuitively correct. Such reasoners fail to scrutinize the form and validity of an argument if it "seems to be the case." Hence, students will shun strategies that may complicate the matter in terms of requiring dialectical skills and counterargumentation on the part of the student in favor of heuristic strategies that generally require less critical effort and lead more swiftly to a conclusion. As a result of this tendency, it is sometimes the case that students confuse the necessary conclusions of a deductive argument with the probabilistic conclusions of an inductive argument.

Cerbin (1988) agrees that students produce underdeveloped arguments because their "makes-sense epistemology" produces few reasons to substantiate their claims and does not attend to counterevidence (other than in a cavalier manner). Accordingly, students simply lack adequate criteria for evaluating the correctness of an argument. Although there are cases to be made in the literature for domain-specific critical thinking skills (McPeck, 1990) and general critical thinking skills

(Ennis, 1990), there does seem to be evidence that the context of a problem (the general field or social circumstances in which a problem is embedded), and student's familiarity with the content of the problem (the specific knowledge base evoked by the nature of the problem), will reflect how effectively the student may reason about it. This view is consistent with Piaget (1972) who had noted that individuals tend to reason at more sophisticated cognitive levels in areas in which they have significant knowledge, interests, and experience. This implies that cognitive structures are influenced by the content and context of the problem to which they are applied. Zeidler and Schafer (1984) found that the context of socio-scientific dilemmas mediated college students' moral judgments on those issues. Dreyfus and Jungwirth (1980) have also found that high school students did not react similarly when equivalent scientific situations were presented in different contexts. Hence, there would appear to be a definitive relationship between a student's underdeveloped arguments and knowledge (or lack thereof) of the subject matter.

Altering representation of argument. Many problems arise when students inadvertently change or modify the original premises of an argument. This occurs when students add, delete, or misrepresent the relationships among the original premises (e.g., confusion of correlational with causational claims). Such premise conversion results in underdeveloped arguments at best and fallacious reasoning at worst. In this case, students form arguments which are based on misrepresentations of the problem at hand. When students have to construct policy decisions based on moral dilemmas involving environmental issues, Zeidler and Schafer (1984) found that they confused hypothetical considerations with matters of fact with respect to the original premises of the problem when reasoning on those moral issues. The premises of the problem under consideration were, quite often, subtly altered by the students. Furthermore, that form of misrepresentation was present in students assessed as having low as well as high moral reasoning ability. Other examples of premise conversion are well documented in the literature (Kurfiss, 1988; Nickerson, Perkins, and Smith, 1985; Perkins, Allen, and Hafner, 1983; Revlis, 1975; Revlin, Leirer, Yopp, and Yopp, 1980).

The topics presented in this section have been synthesized from an array of diverse empirical (quantitative and qualitative) and analytic research efforts. While the implications of this research are multidimensional, the focus of this section has been on varying mediating factors that contribute to errors in students' reasoning that are likely to arise during classroom argumentation. Hence, the implications such research has for science teaching will be more narrowly directed toward a presentation of teacher concerns with respect to the pursuit of classroom discussions.

IMPLICATIONS FOR SCIENCE EDUCATION

The currently advocated focus of science instruction rests clearly upon the interrelationships among science, technology, and society and the fulcrum of curriculum attention to such issues rests with the discussion of relevant personal and societal issues. Although it is not difficult to trace the role of education in relation to personal and societal issues back to Plato's notion of an "informed citizenry," unquestioned contemporary support is not difficult to find (AAAS, 1989; Bybee, Powell, Giese, Parisi, and Singleton, 1991; Collette and Chiappetta, 1989; Harms and Yager, 1981; NSTA, 1982; Rutherford and Ahlgren, 1990; among others). Indeed, the days of rhetoric have ended and curriculum development and implementation are proceeding with fervor.

The all too brief review of logic and reasoning presented on the preceding pages must be considered as more than a nostalgic exercise. Among the more common instructional approaches for attending to students' decisions concerning personal and societal issues are values clarification (Raths, Harmin, and Simon, 1966), analytical decision making (Oliver and Newman, 1967), and the social issues unit design (Collette and Chiappetta, 1989). These approaches, as well as the numerous other approaches with less formalized structures, emphasize classroom discussions and debates on scientifically and/or technologically based issues which are of direct concern to students. The ultimate success of such instructional approaches is at least partially dependent upon students' logical reasoning and argumentation skills. After all, students are expected to participate in classroom debates or construct arguments, within written assignments, supporting a particular viewpoint concerning the issue at hand. Bady (1979), and the testimony of any debate coach, have clearly shown that such skills are not innate to students. Consequently, it appears that students (and science teachers) need to be educated with respect to the conventions of argumentation and formal logic. Adequate instruction in both of these areas should be included in any science course which focuses on the discussion of personal/societal issues just as instruction in the development of social and cooperative skills must be an integrated part of any class which implements cooperative goal structures (Johnson and Johnson, 1975). Just as the "cooperative" group that does not know how to cooperate can undermine the achievement of instructional objectives, so can the use of illogical and fallacious reasoning by students undermine the "informed decision making" and "scientific literacy" objectives of contemporary science-technology-society oriented curricula. The heightened attention which students give to the classroom discourse of their peers (versus that of the teacher) and the significant effects that students' substantive statements have on the learning of their peers has been well documented (Good and Brophy, 1991; Morine-Dershimer, 1983).

In addition to the potential for improving the success of issues-based instruction, a renewed focus on logic, argumentation, and critical thinking requires the adoption of different evaluation techniques than the traditional paper and pencil test. The inadequacy of traditional approaches for the accurate assessment of contemporary curricula goals (e.g., problem solving, critical thinking, decision making, etc.) is well recognized and has recently been eloquently summarized by Wolf, Bixby, Glenn, and Gardner (1991). The evaluation of students' performance for activities which involve no singularly correct answer is generally considered to be subjective and is approached with hesitation by most teachers. However, if we wish honestly to pursue the often-stated goal of scientific literacy for our students, the inclusion of activities (eg., debates group and individual position papers, city council role-plays, and technical reports offering courses of action) which involve discussions, argumentation, and decisions about personal and societal issues are unavoidable.

Hence, science teachers will need to adopt alternative approaches for evaluation. Such approaches will most certainly include what Wolf et al. (1991) refer to as "sampling performances of thought." Since our new curricula value students' thought, thought is what we must sample and evaluate. The aforementioned approach explicitly insists that students take a point of view and support that stance with logic and substantive examples. Clearly, the form and soundness of students' reasoning is most relevant with respect to this evaluation approach and the evaluation of issues-related curricula. It cannot, however, be overemphasized that any movement toward alternative forms of assessment or portfolio-based assessment approaches will not occur without a host of related problems. For example, the development of critical thinking and decision making skills is not accomplished as the result of a single activity or unit. The accomplishment of such curricular objectives is a long-term proposition. Consequently, the classroom teacher will need to focus more on formative evaluations of thought processes within the evaluation plan as opposed to the more commonly used combination of summative measures. Consideration will also need to be given to the development of sound criteria which can be validly and reliably applied to the assessment of students' thought processes. Additionally, the issue of whether relatively individualized alternative forms of assessment (e.g., a portfolio) can be compared across students to assess general group/program status must be resolved.

Of course, the success of the aforementioned instructional and assessment suggestions are contingent upon the adequate education of preservice and inservice science teachers in critical thinking and reasoning skills. As with public school students' thinking skills, the patterns of thought develop over many years. Consequently, simply informing teachers that their reasoning skills are fallacious and inadequate using a direct instruction approach would meet with much resistance and little success. However, within the context of discussions concerning the classroom use of various scientifically or technologically based societal issues, teachers could be presented with hypothetical samples of students' thoughts (for analysis) which exhibit various fallacious arguments. Such an approach would be a psychologically safe way to revise preservice and inservice teachers' reasoning as well as a concrete way to introduce alternative assessment techniques.

The integrated inclusion of personal/societal issues in contemporary science curricula is becoming more of a reality with each passing day. Consequently, it is critical that we provide students with not only the relevant scientific knowledge, but also the reasoning skills necessary to reach informed decisions with respect to these very real and concrete dilemmas. Let us heed a piece of syllogistic advice:

> Decisions about personal/societal issues require critical thinking skills. Students make decisions about personal/societal issues. Therefore, all students need (experience in) critical thinking skills.

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Accepted for publication 29 January 1992