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*Review*

# Teaching Dissent and Persuasion

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**Teaching philosophy should be based on the desired outcome of the teaching. In the case of science education, the guiding principle for a teaching philosophy should start with the desire to help students understand and use science, regardless of their major or profession. To effectively teach students how to understand science, one must include both the content and the process. Peer review is an integral part of the process of science, however it is generally lacking from science education. One must have something for the students to review in order to implement the process education, and *Chemistry Is in the News* offers such a project in the news portfolios. In-class peer review is useful and common in other disciplines, but there is much to be gained by going outside the walls of the institution. Inter-class, in particular interstate and international, compels faculty and students to use Information and Communication Technologies, exposes students to a diverse student body, and provides an opportunity to engage in faculty development via collaboration on instruction.**

**Key words:** Science Communication, Scientific Literacy, Peer Review, Science Teaching Philosophy, Collaborative Learning, Computer-Assisted Instruction.

## INTRODUCTION

### Peer Review

The scholarly community has long had a love-hate relationship with the institution of peer review. The community depends on it to grant "the *imprimatur* of scientific authenticity," (Ziman, 1968) yet deplores how imprecise it is, how it introduces yet another layer of bias and prejudice in the publication process. Many have criticized peer review because it frequently fails to catch errors (Godlee et al., 1998) and fraud (Wade, 1983), stifles innovation by selecting for articles that maintain the status quo (Knoll, 1990), and, worst of all, is a venue through which established researchers deliberately protect their turf (Horrobin, 1990), all to the determent of the progress of science (Smith, 1997). Yet the scientific community continues to allow the fate of careers and the progress of science to hang in the balance and journals tout their peer review procedures as proof of validity and prestige.

The ill feelings toward peer review are a product of viewing peer review simply as a practical tool for quality control (Knoll, 1990). On this measure, peer review may be judged to fail rather miserably, yet is maintained because peer review is analogous to democracy in that, in the words of Winston Churchill, it "…is the worst form of government except all those other forms that have been tried…" (Rennie, 2003). This view of peer review as a practical tool fails to acknowledge the importance of peer review as a social process (Knoll, 1990) that may, imperfect as it may be, serve purposes beyond that of quality control. It also explains why the concept and practice of peer review is largely absent from science education from the most basic levels through doctoral and post-doctoral studies, learned nearly entirely under-

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¶ *Chemistry Is in the News* has been made possible by grants from the University of Missouri, the Camille and Henry Dreyfus Foundation, and the National Science Foundation.

fire by those who practice it (Martyn, 2003). Why would scientists choose to teach this dirty little process, plagued by design flaws, when it is set beside the comparatively clean processes of scientific experimentation where the results can lead to definitive and objective answers?

To see peer review as a social process means not conceptualizing peer review "as a truth-grinding machine but as a discussion among honest and able people, working within the social system of institutionalized science, making the clearest sense they can of the information they all share," (Knoll, 1990). This view returns to the roots of formalized peer review in the seventeenth and eighteenth century (Kronick, 1990). At this point peer review was seen as both a quality control mechanism in order to protect the prestige of the societies that sponsored journals, but also as a means to work out a minimal amount of consensus in the scientific community about new developments. For example, the Literary and Philosophical Society of Manchester printed the follow disclaimer:

> The sanction which the Society gives to the work, now published under its auspices, extend only to the novelty, ingenuity, or importance of the several memoirs which it contains. Responsibility concerning the truth of facts, the soundness of reasoning, in the accuracy of calculations is wholly disclaimed: and must rest alone, on the knowledge, judgement [*sic*], or ability of the authors who have respectfully furnished such communications (Kronick, 1990).

The adoption of this view of peer review also has implications for how to conceptualize the scientific research enterprise. Peer review is a large component of the science legitimatization mechanism. Though peer review has an educative effect for the individuals involved, the authors, reviewers, editors, and readers as an article works its way through the process (Williamson, 2003) to ignore the social dimension of science is to ignore how we come to know what we know. As Ziman (1969) explained:

> We fail to realize that scientific research is essentially a corporate activity in which the community achieves far more than the sum of the efforts of its members. It is not enough to observe, experiment, theorize, calculate and communicate; we must also argue, criticize, debate, and expound, summarize, and otherwise transform the information that we have obtained individually into reliable, well established, public knowledge.

This process of transformation to public knowledge is not, however, he added, to get it printed and distributed for other persons to read. Scientific knowledge is more than this. Its facts and theories must… have been found so persuasive that they are almost universally accepted. The objective of science is not just to acquire information nor to utter all non-contradictory notions; its goal is a *consensus* of rational opinion over the widest possible field (Ziman, 1968).

It is this discourse that is the essence of science. As Bronowski (1965) writes, "Dissent is the mark of freedom, as originality is the mark of independence of mind. Originality and independence are private needs for the existence of a science, so dissent and freedom are its public needs". Without dissent, science ceases to have value of truth. Habermas (1991) takes this one step further, maintaining that the *systems sphere*, containing science and technology, is not legitimate if it is not integrated with the *culture sphere* of life, containing culture, morality, public, and private life. Successful human evolution as a *collective learning device* requires effort to discuss and bring about consensus about the *systems sphere* in the *cultural sphere* so as to guarantee democracy. If laypeople in a society do not accept the products or procedures of the systems sphere, then the systems sphere (science and technology) loses its authority and its discoveries become meaningless in the context of the wider society. Thus, the greatest meaning of the process of discourse is to make the information corporate and communal knowledge through debate and persuasion.

## Scientific Debate and Science Education

If the transformation of information into corporate knowledge is so central to science and peer review is an essential element in this transformation, why is science in general, and chemistry in particular, taught as it is? Polanyi (1946) outlines the three phases of science education:

> School science imparts a facility in using scientific terms to indicate the established doctrine, the dead letter of science. The university tries to bring this knowledge to life by making the student realize its uncertainties and its eternally provisional nature, and giving him [*sic*] perhaps a glimpse of the dormant implications which may yet emerge from the established doctrine. It also imparts the beginnings of scientific judgement [*sic*] by teaching the practice of experimental proof and giving a first experience in routine research. But a full initiation into the premises of science can be gained only by the few who possess the gifts for becoming independent scientists, and they usually achieve it only through close personal association with the intimate views and practice of a distinguished master.

Unfortunately, this taxonomy is more theoretical and ideal than actually practiced. Chemistry instruction at the

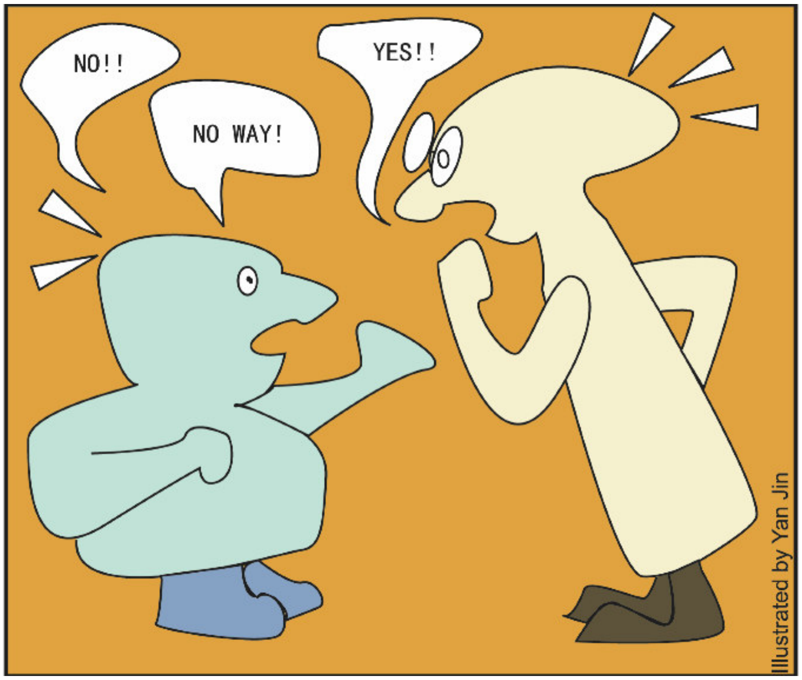


**Figure 1.** Dissent, sometimes presented heatedly and emotionally, is an essential component of science and science education.

university level is still largely confined to the transmission of the 'dead letter of science,' via lecture. Thus, university chemistry instruction fails to communicate the debate and dissent that truly characterizes science. This has several implications.

First, teaching chemistry in this way makes it inherently less interesting to study by portraying it as inert and static as opposed to evolving and dynamic. In the context of chemistry education, this is particularly salient because of the shrinking proportion of future chemists among the students who are filling chemistry courses. Students who will never step foot in a chemistry lab after graduation question why they should learn what the structure of ethylene is or how to determine the chirality of a molecule. It is an uphill battle to entice these students to see the discipline as worthwhile, if not a little interesting; they even lack the incentive of foreseeing cleverly producing this information at a cocktail party – at least to any great effect–as they might when studying the humanities (Livingston, 2005).

Second, this method of instruction makes learning much more difficult for students. The material is presented to students in lectures or textbooks as settled facts and concepts to be accepted and memorized, and the development of facts and concepts, including the debate, dissent, and disagreement that took place, is ignored. This process of development illustrates the inherent beauty and logic of science and chemistry, which, though its results may sometimes be surprising, make it more natural to understand.

Third, and most important, teaching without showing that that dissent and debate characterize science (Figure 1) fails to prepare students to navigate a world increasingly dependent on scientific information as educated people. When students lack the appreciation for the debate and discourse that characterize science, they are ill-equipped to understand what is occurring on the cutting-edge of science and medicine. This is problematic in a world where the "cutting-edge" that they learn in class will be outdated within the decade due to the rapid rate of scientific advancement taking place (Hargis, 2001).

## Chemistry is in the News

It is a tremendous mandate to teach students to not only know science but to understand its process, and, as alluded to above, the most common methods of teaching fall short. *Chemistry Is in the News* (*CIITN*) is an answer to this challenge, taking a step toward integration of the spheres by addressing the philosophical underpinnings of science while attempting to improve instruction. This curriculum uses current news articles to explain the chemistry that is being taught in lecture. It is an exercise in active learning as collaborative groups of students first read the news article and interpretive comments and answer questions in the *CIITN* news portfolio, then gather their own news article and information and write interpretive comments and questions for their peers (Glaser and Carson, 2005; Hume et al., 2005; Carson et al., 2006; Carson and Glaser, submitted). This process encourages students to build connections between the course content and the real world—between the systems sphere and cultural sphere—and asks them to critically examine their assumptions, both scientific and social, leading to the construction of new *cognitive schemas* (Hume et al., 2005).

*CIITN* has accomplished the integration of peer review into science instruction by merging current events and the exploration of the chemistry concepts. *CIITN* has been employed successfully at the University of Missouri-Columbia (MU) for nearly a decade using in-class peer review. This model has been integrated in courses at number of other institutions included the University of Colorado-Denver (UCD), Florida State University, University of Ontario Institution of Technology (UOIT), and the University Paderborn. Beginning in 2002, inter-class peer review has taken place between the MU and UCD and international inter-class peer review is being pursued with UOIT and the University of Paderborn.

The process of science would be incomplete without a review, and so science education should include it as well. Thus, *CIITN* is completed when students peer review each other's *CIITN* news portfolios. This can take place at one of two levels: intra-class and inter-class, particularly between classes in institutions that are in different states or countries (Glaser, 2003). Whereas in-class peer review involves classmates assessing each others' projects, inter-class peer review involves students at different institutions assessing each others' work. Inter-class peer review between neighboring institutions is consequential in that the students are being taught by different instructors in different ways. However, the significance increases as the institution become more distant, in other states or even other countries, as the students will have more varied backgrounds and a wider variety of perspectives on issues under debate by virtue of living in different locales. While in-class peer review is common in other disciplines and is being adopted slowly in the sciences (Russell et al., 1998), inter-class peer review is novel, and one must ask what the additional benefits are and whether they justify the increased organizational effort that coordinating two or more courses at different institutions demands. These benefits go beyond simply improving test scores and the five leading benefits are summarized below. This review is meant to be a starting point for prospective *CIITN* faculty.

## Introduces Students to the Process of Science

The central benefit for the instruction of chemistry is that *CIITN* exposes students to the scientific process and gives them the opportunity to take part in it when it employs peer review. Much of the general public is unaware of the process by which research findings are accepted and published. Therefore the public is often unable to critically judge the information relating to science they receive from sources of a variety of levels of credibility as they might find in the popular press and on the Internet. When students peer review each other's work, just as scientists do, they gain an appreciation for the safeguards, as well as the shortcomings (Knoll, 1990) in this process and are better equipped to interpret scientific evidence both as scientists and as laypeople. While this could be accomplished to some degree with in-class peer review, it is more effective when done inter-class, which leads to another reason for inter-class peer review.

## Achieves More Accurate Peer Review

Though the results of studies examining various formats of peer review, including blinding, unmasking, signed reviews, have shown that there is little difference in their ability to produce accurate, objective review (Goldbeck-Wood, 1999), the same is not to be expected for peer review in the classroom. When students peer review work from another class, it is by design truly anonymous because the students are geographically separated and lack relationships that exist either between researchers in the same field or students in the same classroom. In inter-class peer review, the students have the opportunity to evaluate the news portfolio divorced from the students who created it. As a result, students do not have to fear the social consequences of giving poor evaluations (Lin et al., 2001) and students engaging in inter-class peer review do not have positive or negative personal feelings for other groups' members coloring their judgment, which makes the reviews more accurate. Thus, *CIITN* peer inter-state review manages to introduce protection against the inter-personal weaknesses that plague professional peer review (Godlee et al., 1998; Horrobin, 1990; Knoll, 1990; Smith, 1997; Wade, 1983). While this could be accomplished in principle with anonymous in-class peer review, students are frequently able to determine who is responsible for their evaluation; consequently the opportunity for iterated anonymous peer review, which allows students to learn from their peers and from their mistakes, is limited.

## Teaches Students How to Meet the Responsibilities of Scientists

While anonymity of inter-class peer review provides an expanded opportunity for fair and unbiased peer reviews, it also encourages students to write for a broader audience. This is a very important skill for scientists to obtain, as they are responsible for defending their work not only to other scientists, but also to the general public (Kovac and Coppola, 2000). Scientists are also responsible for promoting science literacy by making science more accessible. This, however, has been dismally neglected, despite institutional encouragement (National Research Council, 2003). Aside from the exercise of preparing for a wider audience, in peer revi-

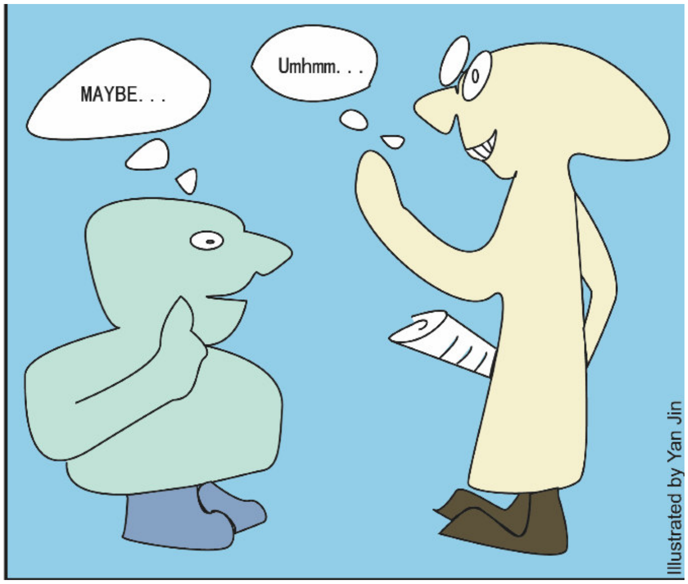


**Figure 2.** Continuous debate and growing understanding of contrary arguments leads to a consensus, which is the desired final stage of the scientific process.

ew, students are exposed to a larger variety of opinions emanating from a more diverse body of students. As a result, students become more tolerant and this also prepares them to fulfill another responsibility of scientists, to engage in a dialogue with the public so that science "will better reflect society's current needs and values," (Leshner, 2003). This is a long-term benefit of inter-class peer review, particularly that which takes in classes that are geographically distant: *CIITN* teaching students to become more sensitive to the consequences of science and public policy outside their own locale and to the reception of their message by a heterogeneous audience.

## Provides an Opportunity for Faculty Member Development

A welcome social benefit for inter-class peer review is communication between faculty members. As scientists, professors have many colleagues with whom they converse; as educators, however, many professors' lists of contacts shrink dramatically. The Internet provides the same opportunity for faculty collaboration on education as it does for collaboration on science, but only the latter has been realized. *CIITN*, when utilizing inter-class peer review, uniquely unites instructors in a joint endeavor: witnessing and learning from the fellow instructors' strategies, and engaging in both formal and informal discussions and reviews about improving teaching (Louie et al., 2003; Shere et al., 2003). This process taken outside of the institution becomes more formative, less threatening, and more effective. In addition, both students and faculty need to become increasingly inclusive in their outlook as both personal and professional communities become more global. The *Chemistry Is in the News* curriculum, including inter-class peer review, propels both groups toward that goal.

## Information and Communication Technology

*CIITN* inter-class peer review finally offers a very practical and concrete benefit in employing Information and Communication Technology. Inter-class peer review has only become possible with the advent of Information and Communication Technology (ICT) because of the geographical separation of the students engaging in inter-class peer review. While universities provide ample access to ICT to their students and faculty, its utility has not been fully realized (Cuban, 2003) largely due to the increased workload it entails (Ayers et al., 2003). The Internet is used in *CIITN* as an information resource, recognizing that the "teacher as primary source of knowledge no longer suffices in a world where knowledge doubles every seven years and 10,000 articles are published every year" (Hargis, 2001). It also serves as a forum to publish students' work and a medium for communication between students and faculty (Wu and Glaser, 2004; Wu et al., 2004) as with the *CIITN* website (ciitn.missouri.edu). In addition, it is appropriate for students to be engaged in the use of ICT; familiarizing all students with ICT is fast becoming necessary preparation (i.e. authentic performance) because the Internet is an increasingly essential communication tool for professionals. Thus, the exercise in using ICT is another benefit of inter-class peer review.

The benefit ICT use in inter-class peer review is multifaceted. Aside from students exercising skills they will need after graduation, current learning theories also suggest that people need to construct their own knowledge (Bodner et al., 2001; Gilmer, 2002). The use of the internet facilitates constructivist learning by providing numerous information outlets to explore, where "students become active participants in their own learning, self motivation, student inquiry…" (Hargis, 2001). Additionally, studies show that students are better motivated and gain a better understanding of the material learned through constructivist methods using technology (Niederhause et al., 1999).

## Conclusion

The peer review process has long been part of the establishment of scientific fact. Though it is not perfect from a technical standpoint and has, at times, failed to weed out scientific fiction, its remains of paramount importance to the scientific community as well as society at large. This is because science is not only a craft practiced in secluded laboratories but a social process that dependent on consensus among practitioners as well acceptance from laypeople (Figure 2). If science is to be properly understood by the public, science education must start with this concept as the cornerstone, and peer review must be brought from the dusty volumes of journals that undergraduate never visit into the classrooms that they inhabit. The integration of peer review into the science classroom provides other benefits aside from informing the public of the nature of science. It also makes the science more interesting and prepares those pursing a career in science to better fulfill their responsibilities while giving the instructors an opportunity to engage in collaboration.

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