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Confronting Doubts About the Intelligibility, Plausibility, and Fruitfulness of Inquiry-based Instruction

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Our two prior *ISTJ* editorials in the *Iowa Science Teacher Journal* (Clough & Kruse, 2010a & 2010b) have applied a conceptual change framework (Posner, Strike, Hewson & Gertzog, 1983; Pintrich *et al.*, 1993; Abd-El-Khalick & Akerson, 2004; Clough, 2006a) to understand the difficulties students have in abandoning their intuitive ideas about the natural world and, for the same reasons, the difficulties teachers have in jettisoning their intuitive ideas about teaching and learning. Our last editorial noted that in both cases, dissatisfaction with prior ways of thinking must be achieved before alternative ways of thinking will be seriously sought and considered. To initiate a sense of dissatisfaction with intuitive common teaching practices (i.e. lectures, textbook readings and questions, worksheets, and highly directive activities), we noted the overwhelming evidence that such practices have not promoted conceptual understanding of science concepts or other equally important goals for science education. We also emphasized how easily these kinds of teaching practices can be emulated by machines, a point we hope raises not only questions, but also indignity, regarding the pervasive nature of those teaching practices.

However, once dissatisfaction with previously held ideas is achieved, a new idea that is intelligible, plausible and fruitful must be available (Posner, 1983). That is, for those experiencing dissatisfaction with old ideas to entertain new ideas the new ideas must be understandable, reasonable, and solve problems associated with the former way of thinking. As an analogy, consider that the first rule of walking on the wing of a biplane is not to let go of what you are holding onto, no matter how dissatisfied, unless you first have a grip on something else. In a very real sense, ideas with problems are more useful than no idea at all. Returning to our sinking and floating example from our previous editorial, students who acknowledge the problems with their intuitive ideas regarding why things sink and float will still not let go of those ideas unless they have another idea that helps to make sense of the phenomena. Similarly, science teachers who are dissatisfied with traditional science instruction may continue to rely heavily on textbooks, cookbook labs and lecture feeling no viable alternative approaches exist.

Before putting forward an alternative research-based approach to traditional science teaching practices, we want to be clear that the core problem with the ubiquitous use of traditional practices is that they fail to mentally engage learners, in part, because they "do not take in to account students' prior knowledge, lack representations to clarify abstract ideas, and are deficient in phenomena that can be explained by the key ideas" (Stem and Roseman, 2004, p. 538). We are *not* arguing, nor does the research support, that teachers should never provide information, that textbook readings should never be assigned, or that directions regarding laboratory and other activities should never be given. We *are* arguing, and overwhelming research does support, that these science teaching practices are far too prevalent, rarely used judiciously, and neglect well-established research regarding teaching that promotes deep and robust conceptual learning.

Unlike the traditional transmission approach to teaching science, effectively teaching science as and through inquiry reflects what is known about how people learn and promotes all the goals we have for science education (Clough, 2006b). Clough (2006c) writes:

> Well planned and effectively implemented inquiry experiences encourage students to be both mentally and physically engaged in ways that are not possible in other science education experiences. The decisions that students make when inquiring compel them to access their prior knowledge, apply it to the situation at hand, and assess their progress. All this requires extensive mental activity and reflects what we now know about how people learn science. (p. 2)

Not surprisingly, students in inquiry-based or interactive classrooms repeatedly outperform students in traditional classrooms on content measures (e.g.: Chang & Mao, 1999; Hake, 1998; Jensen & Finley, 1996; Schroeder et al., 2007; Wise & Okey, 1983). When compared to more inquiry-based teaching, traditional teaching (textbook, lecture, prescriptive labs) do not as effectively promote critical thinking, self-regulation, reflective thought, or elaboration (Schraw *et al.*, 2006; Sungur & Tekkaya, 2006). Furthermore, students' attitudes toward

science are more positive after inquiry-based instruction than after traditional instruction (Chang & Mao, 1999; Kyle et al., 1988; Sunger & Tekkaya, 2006). These and other well-established positive outcomes establish inquiry science teaching as a viable and fruitful alternative to traditional science teaching practices.

Of course, conceptual change is rarely straight-forward. That learners of all ages find objections to new ways of thinking is not surprising, and effective teachers recognize this and carefully address those objections in order to promote deep conceptual understanding and application of accepted scientific ideas. Just as students often raise objections or misunderstandings of newly introduced science ideas, science teachers raise understandable concerns about inquiry science teaching. These objections regarding the intelligibility, plausibility and fruitfulness of inquiry-based science teaching are understandable and expected in light of conceptual change theory.

The additional time that inquiry science teaching requires and the perceived need to cover science content is perhaps the most significant concern teachers report. This reflects the often cited "mile wide, inch deep" science curriculum that results in overstuffed, but undernourished, science lessons. We must carefully consider the difference between simply covering content versus teaching it in a manner that students *really* understand it. Examining what appears in the curriculum for what are truly fundamental science concepts, as opposed to simply teaching what appears in the textbook, is an exercise that all science teachers should periodically contemplate. Many science teachers wrongly think that their students will suffer if they parse out and teach only the fundamental science ideas, but this is what college professors and reform documents have for years sought from secondary school science teachers (AAAS, 1989, 1993 & 2001; NRC, 1996; NSTA, 1998). Worrying about the efficiency of inquiry science teaching is often the most significant concern of science teachers. However, efficiency is a measure of accomplishment per time. Yet, if accomplishment is defined as deep, applicable, and transferable conceptual under-standing of science content, teaching science through inquiry *is* more efficient than traditional science teaching practices.

Today's high-stakes testing environment raises another content-related issue – the fear that inquiry does not prepare students for such exams. First, many high-stakes exams like the ACT or SAT directly assess students' reasoning abilities more than knowledge of specific facts. Such reasoning and critical thinking are explicitly promoted in an inquiry-based classroom, but are glaringly absent from traditional instruction in which most decisions are made for students. Sometimes high-stakes tests are used as a scapegoat for not teaching science as and through inquiry.

For instance, while teaching middle school a few years ago, the first author attended a faculty meeting where the point was made that because the science curriculum did not cover birds, students had not done well on a particular standardized exam question. However, the particular question required reasoning, not specific knowledge about birds. The issue was not a lack of teaching content, but a lack of teaching students to think critically and reason logically. Second, recall that teaching science through inquiry better promotes conceptual understanding of science concepts. If students deeply understand science concepts, they will be better prepared for high-stakes tests than if they simply memorize and regurgitate factoids. Finally, rather than accept trivia-based exams, teachers and education reformers are and should continue to fight for assessments that truly do measure conceptual understanding of fundamental science ideas, reasoning, and other intellectual ends crucial in the 21st century.

Another concern about inquiry-based instruction is whether the approach can effectively teach advanced science concepts. While teaching advanced concepts through inquiry takes considerable skill, the answer is a resounding "yes!" The Iowa Science Teachers Journal is devoted to assisting science teachers effectively teach science, and several articles address sophisticated approaches to teaching complex science concepts including biological evolution (Kasuga & Evans, 2009), genetics (Robinson, 2006), polar and non-polar interaction (Kruse, 2005), and thermal energy (McLaughlin and Bajpai, 2009). Each of these articles provides detailed description of how teachers can encourage students to mentally wrestle with these sophisticated topics through inquiry-based strategies. No doubt we all struggle at times to teach particular topics through inquiry. But we persist in our efforts, talk with our colleagues, read professional science teacher journals, and attend professional science teacher conferences to improve our practice. The research base underlying effective science teaching and our hard-earned professional knowledge is what separates us from the intuitive notions that others have about teaching and learning.

Another concern with inquiry stems from the mistaken idea that inquiry science teaching means that students

will discover science ideas on their own. The history and nature of science makes clear that most science ideas are counter-intuitive (Wolpert, 1992; Cromer, 1993; Matthews, 1994), and students will not come to the desired scientific understanding without well-reasoned teacher intervention that effectively scaffolds them to that understanding (Clough, 2002 & 2006c). However, that intervention is considerably different than simply telling students the accepted science idea. Instead, inquiry-based instruction demands that teachers carefully scaffold student thinking using questions that assist students in making the logical connections that lead to understanding the targeted science idea. At times, that *does* mean providing students with information, but only when that information will make sense to students and is crucial for the needed connection. Thus, information is purposely and judiciously provided at times, but only when appropriate and with the explicit purpose to relieve students' cognitive conflict or provide a scaffold for student learning. Most importantly, this information is provided after students have investigated related phenomena and mentally wrestled with concrete examples. In this way, the new information is more likely to be seen as important and understood.

Classroom management is another concern teachers have regarding inquiry-based science teaching. Lectures, textbook readings, worksheets and cookbook labs all reduces the complexities of teaching science, but they largely do so by reducing student mental engagement and decision-making (Clough, 2006d). When students are actively learning through inquiry, the classroom space will often look and feel more chaotic than when students are passively listening to a lecture. Yes, teachers must be more attentive to students when teaching science through inquiry, but that increased attention means we are paying more attention to what students are doing and thinking. That information is crucial for effective teaching and effectively managing students. However, students are more on-task during meaningful inquiry instruction precisely because they have to think more carefully about what they are doing. Every teacher knows that when students are deeply engaged in what they are doing, classroom management issues are significantly mitigated. That said, constantly walking around the room, positioning yourself so that you can observe what all students are doing, carefully listening to students, and interacting with them are all crucial classroom management *and* effective teaching behaviors.

Lack of funding for equipment and supplies can also be seen as reason for not conducting inquiry laboratory activities. However, effectively engaging students in meaningful and sophisticated science inquiry need not require expensive laboratory equipment or supplies. Teaching science concepts via inquiry can be accomplished in a number of inexpensive ways and these are illustrated in many articles appearing in *ISTJ*. Even very complex chemistry concepts can be addressed via inquiry using baking soda, vinegar, and plastic bags (Clough & Clark, 1994a & 1994b). Furthermore, complex equipment, if introduced before students understand key concepts, can become a black box that masks the phenomenon and actually interferes in students' learning (Olson and Clough, 2001).

Moving toward inquiry science teaching demands that the approach be seen by teachers as intelligible, plausible, and fruitful. The *ISTJ* editorial team works long hours to ensure that editorials and articles appearing in the journal convey that teaching science through inquiry meet those demands. We carefully work with authors so that all articles: (1) make clear what inquiry science teaching looks like and the teacher's crucial role in that approach (intelligible); (2) convey how inquiry can be effectively implemented by teachers in authentic, complex, and dynamic classroom environments (plausible); and (3) will promote inquiry that results in deep thinking and learning by students (fruitful). Yet, conceptual change takes effort, time, perseverance, and faith – matters we will address in our spring 2011 *ISTJ* editorial.

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