Minimizing resistance to inquiry-oriented science instruction: The importance of climate setting.

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Establishing and maintaining a classroom atmosphere conducive to student learning should be a goal for all teachers. As science teachers shift from traditional didactic forms of instruction to inquiry-oriented instruction, they sometimes encounter resistance from students, parents, administrators, and even teaching colleagues. In advance of and following changes in classroom pedagogy, it is imperative that teachers properly consider and take actions to set and maintain an appropriate atmosphere. Teachers must also be prepared to react to negative external influences that might originate with parents, administrators, and fellow teachers. The author describes several forms of resistance, and offers techniques of climate setting that, if used properly, can alleviate concerns and help create classroom, school, and community atmospheres conducive to student learning via inquiry.

Resistance to Inquiry

The author of this article is project director of a grant-funded initiative* to introduce and sustain inquiry-oriented science instruction in the Chicago metropolitan area. The *Chicago ITQ Science Project* is a school-university partnership involving 24 high school physics teachers and their designated administrators, as well as two expert Modeling instructors, two experienced Modeling mentors, and three knowledgeable university-level teacher educators. All participants (with the exception of the administrators) met daily for three weeks during the summer of 2005 at Dominican University to learn about and practice the Modeling Method of Instruction. During several autumn follow-up meetings, it became evident that participating physics teachers were experiencing a small but discernable degree of resistance to inquiry originating with certain students and parents. While school administrators were committed to supporting their Modeling physics teachers, they sometimes experienced this resistance themselves from students and parents, but weren't always adequately prepared to defend the use of inquiry in the classroom. Finally, some teaching peers in high school science were skeptical of the inquiry practices being used in the Modeling approach. It has become clear that it is imperative for teachers who introduce inquiry methods into a school system – where "teaching by telling" is the status quo – understand the role that climate setting plays in creating an atmosphere that is conducive to inquiry-oriented science instruction.

Student Resistance: Our Project's teachers have experienced several types of student resistance to inquiry with varying degrees and frequencies. Some students resist inquiry if they perceive it as a threat to them achieving high grades. Good students, but especially borderline "A" students who have done well under the more traditional "teaching by telling" mode of instruction, tend to find learning more challenging in a classroom where there is strong reliance on inquiry. Some students who have succeeded well under the old system of didactic instruction now feel threatened by a constructivist approach. Such an approach requires them to do more than merely memorize and replicate information on tests, and conduct number crunching with formulas and calculators. Some students express a strong sense of frustration of not "knowing the right answer," instead of having to arrive at it on their own using the inquiry process. They sometimes indicate that they would like more lecture and reliance on a textbook than is common with constructivist approaches. They want teachers to "have the final word" or to have the instructor speak "with one voice." It's not unusual to hear students say something to the effect, "I'd rather be told what I need to know" or "I don't know what I need to know." In the long term, these concerns can lead to student disengagement characterized by passivity, calculator gaming, doing other homework in place of participating in class, or working only on those projects which are perceived to be of value in the course grade while letting others do the non-scored work. Some students will wait for others to begin work, and only then follow other students' leads. Students sometimes will not take notes unless the teacher is speaking; the value of other students' commentary is deemed questionable if not worthless. Students sometimes undermine a lesson by shouting out the answer if they know it by another means. At other times they strongly resist participating in discussion or Socratic dialogues for fear of being wrong. Much of this resistance slowly dissipates as students become more comfortable with inquiry practices, but at the outset the introduction of inquiry practice does lead to some difficulties for both students and teachers.

Parental Resistance: An examination of compilations of posts to the Modeling Listserv at the Arizona State University Modeling Instruction website** (e.g., Parent Attitudes re New Modelers, Selling Modeling to Parents, Parental Pressure and Grades) show that teacher concerns about parental attitudes are well founded. However, the degree of parental resistance is, in most cases, significantly less than that originating with students. Parental resistance typically originates from students complaining to their

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** *http://modeling.asu.edu*

parents. The complaints can be varied, but parents become concerned and vocal when they perceive that their children's education is "threatened" by non-traditional approaches. Some parents are concerned about adequate subject matter delivery and wonder how inquiry approaches will affect future success in school, college, or university life. How will the slower pace of inquiry impact student learning, and how will this affect standardized test scores such as the ACT exam? They don't understand why an inquiry-oriented teacher isn't always teaching directly from a textbook, or perhaps not using a textbook at all. Because instruction is classroom intensive and student- and assessment-centered (learning from empirical observations and Socratic dialogues for instance), parents become frustrated when they don't know how to help their children. Tutors are sometimes hired to provide assistance. Parents, based on their own experiences with physics, will sometimes wonder, "Why aren't you teaching them as much physics as I learned in high school?" or "Why are you watering down the curriculum?" Parents who want to vent might write "nasty e-mails" to teachers, or do an end-run around a teacher and go directly to the school administration with a complaint. Fortunately, after adequately addressing parental concerns, resistance from this quarter appears to rapidly diminish.

Administrator Resistance: A school administrators' resistance (departmental chairperson, school principal, or superintendent) to inquiry might stem from complaints by students and/or parents. Additional questions might arise from concerns about high stakes testing such as that associated with No Child Left Behind legislation. Other forms of resistance might originate from the fact that inquiry teaching does not align well with assessment instruments designed for use with didactic teaching styles. Fortunately, no such resistance has been encountered in this project due to the fact that school administrators were brought onboard early in the project, and were provided substantial information about Modeling goals, processes, and benefits. They also were given a scoring rubric designed specifically for assessing the quality of inquiry-oriented teaching. They have been periodically updated with information about teacher experiences, and have been provided additional background information in a timely fashion to help them cope with concerns expressed by parents and students.

Peer Resistance: More traditional science teachers sometimes are concerned about not "covering" enough subject matter due to the "slowness" of inquiry. They are sometimes concerned about the methods of inquiry due to a failure to understand the philosophy, pedagogy, and benefits associated with inquiry-oriented instruction. Because student attitudes about science and an instructor can be strongly affected by the degree of active involvement, some peer teachers are concerned about "popularity contests." This can result in strong student preferences for one subject over another or one teacher over another. Teaching peers sometimes fear being "forced" to use an inquiry approach with which they are unfamiliar or uncomfortable.

Student, parental, administrator, and peer teacher resistance to the use of inquiry-oriented instruction in the science classroom potentially could have deleterious - if not debilitating - consequences for teachers of inquiry if not properly addressed. A teacher's commitment to the approach can be reduced when confronted with mild and periodic forms of resistance, or at least make him or her question what he or she is doing. Being confronted with significant and on-going resistance can result in the new inquiry teacher returning to the older form of direct instruction. Unless all persons with a stake in the process of learning via inquiry are provided with a broad understanding of the reasons for its implementation, the use of inquiry-oriented instruction in the science classroom will be threatened. There are steps, both proactive and reactive, with which teachers using inquiry-oriented instruction should be familiar. A teacher can either work proactively to prevent resistance to inquiry, or can work reactively to respond to resistance after it originates. In the author's opinion, the former approach is to be preferred. It is easier to change people's attitudes if they have no preconceived notions about inquiry procedures; they are willing to listen, and might be positively supportive of a new teaching approach if they understand it and can foresee the benefits of its use. It is much more difficult to change minds after people develop prejudices; prejudice is a strong impediment to educational change. With these points in mind, how then does one work with students, parents, administrators, and peer teachers to minimize, if not altogether eliminate, resistance to inquiry-oriented instruction? The approach consists of properly using climate setting to establish a receptive atmosphere in the classroom, school, and community.

Classroom Climate Setting

Whole Group Climate Setting: Classroom climate setting refers to creating the correct intellectual atmosphere under which inquiry-oriented instruction will be conducted. Successful climate setting addresses two critical components - the role of the teacher and the role of the student (Roth, 2003). Because inquiry-oriented teaching is conducted under what is for some students a very different classroom atmosphere, climate setting needs to be part of every inquiry-oriented teacher's management plan. In climate setting teachers help students understand the difference between the traditional direct instruction and inquiry-oriented instruction. For instance, students need to understand that the authentic role of the teacher is to prepare situations through which students can learn. Students must understand that learning is their responsibility, and that teaching doesn't necessarily translate into learning. The teacher explains that he or she will set up a problem, anticipate student needs, and provide access to needed resources. The teacher will play the role of mentor, and students will work cooperatively to solve the problem presented. Teachers must stress that the roles of teachers and students change. Teachers are no longer to be seen as purveyors of information; rather, they are to be seen as facilitators of student learning. Students are no longer to be seen as empty receptacles to be filled by teachers; rather, they are to be seen as active inquirers. Students no longer rely and teachers and textbooks for their learning. They must take responsibility for their own learning, and construct knowledge from experiences.

Teachers should make clear to students that teachers might ask questions even if they know the answer; that they might ask "why?" two or three times in a row, that they might ask students to explain and justify their conclusions on the basis of evidence. Teachers must point out that questioning an idea does not mean that it is wrong. Students need to understand that their role is to speak up, confront apparent fallacies, and ask questions when they don't understand. They must see the educational process as the construction of knowledge in which ideas derived from experience are clearly stated and clearly evaluated. They need to know that no question is "stupid," and that the only poor question is the question that is not asked. Students must have an understanding of this changing climate, and these differences should be pointed out early and often. Initiating climate setting should be done at the very outset of a course. It should be done on a daily basis thereafter until the classroom atmosphere is clearly and strongly established as one that supports and sustains inquiry. Such a classroom climate setting process might seem overly repetitive, but experience has shown that it is extremely important for successful inquiry-based instruction. Done this way, problems can be avoided to the greatest possible extent.

Climate setting might be thought of as a process of "negotiating" the classroom atmosphere. Teachers who employ inquiry-based instruction need to be fully cognizant of the fact that students can interpret classroom activities in variety of ways, some of which can be antagonistic to inquiry. In the first column of Table 1 the reader will find a number of specific inquiry-oriented practices. In the next two columns the reader will find how students could interpret these practices. The second column relates to a more traditional interpretation, and the third column refers to the intended interpretation most suitable to the inquiry-oriented classroom. Teachers can use these distinctions to help

Specific inquiry-oriented teacher practices	**Traditional interpretations of teacher inquiry practices**	**Intended interpretations of teacher inquiry practices**
teacher asks questions of students	teacher's questions imply evaluation, monitoring, and efforts to control students	teacher seeks clarification and elaboration of students' ideas
teacher focuses on questions rather than answers	teacher doesn't understand the content of this course	teacher is interested in having us understand how scientist know what they know
teacher deflects "simple" questions to other students, or answers one question with another	teacher doesn't know the answer, or the teacher is too lazy to answer the question.	teacher wants us to learn how to think for ourselves, and/or learn from others
teacher engages a single student in an extended discussion while most of the class waits	teacher believes that the student must misunderstand or has the wrong idea; this attention is unfair to the rest of the students	teacher appears to believe that the student has something uniquely valuable to share, and is providing an opportunity for other students to learn from someone other than the teacher
teacher makes very selective use of or de-emphasizes use of textbook	teacher is a "big shot," and wants to show us what he or she knows	teacher wants us to learn from nature, not authorities
teacher engages students in active and extended scientific inquiry	teacher wants the students to do all the work while (s)he merely wanders around the lab; doesn't care if we learn	teacher wants students to understand the methods of scientific experimentation, and how scientists come to know
teacher provides opportunities for scientific discussion and debate among students	teacher doesn't care what we learn or if we are confused	teacher wants us to see that science is a social compact, that knowledge is empirical and depends upon a consensus among scientists
teacher works to make student understanding visible through student presentations and student answers to questions	teacher wants students to feel inferior, stupid, or incapable	teacher wants to know what we think we know so that misconceptions can be identified, confronted, and resolved
teacher spends time on conceptual development at the expense of back-of-the-chapter exercises	teacher doesn't have a good understanding of the phenomenon under study and wants to hide ignorance of exercise-working skills	teacher really wants us to understand the concepts of science, not just mathematical number crunching employing formulas
teacher focuses on depth of understanding rather than breadth of coverage	teacher doesn't want students to know that (s)he has limited knowledge of the subject matter	teacher wants students to understand the content, processes, and nature of science by studying fewer topics in greater depth

Table 1. Negotiating the classroom atmosphere by providing alternative interpretations of inquiry-oriented teacher practices. Many of the above characteristic activities come from *National Science Education Standards* (NRC, 1996.)

their students understand the value of what it is that they do when they employ various inquiry-oriented practices.

Small Group Climate Setting: Successful group-level climate setting does not assume that students possess the requisite social skills to work cooperatively. Because cooperative approaches to education tend to depend strongly on teamwork, teachers must clearly state expectations for student interactions. They must not assume that students will have a good understanding of what it means to work cooperatively. Teachers must assist students in gaining an understanding of the social aspects of cooperative work. They must assist students to clarify tasks and procedures, and work together equitably and fairly to attain a common goal. The teacher must help students understand that the solution of a presented problem belongs to them, not the teacher. Below are several team-level participation rules adapted from Roth (2003) for student-on-student interaction within teams. Each team member will:

- be present and ready to work, contribute to the project, and do the work assigned
- communicate accurately and unambiguously, fully expressing ideas
- substantiate claims using evidence
- pass judgments on the value of ideas and not individuals
- ask questions when an idea or fact is presented that they do not believe or understand

In addition, teachers might also want to include the reflective group processing approach mentioned by Johnson, Johnson & Holubek (1988) to help students understand what works and doesn't work from an interaction perspective.

Individual Climate Setting: Perhaps one of the most overlooked components of education in traditional and inquiry-oriented classrooms alike is the role of metacognition and its relationship to student self-regulation. Metacognition – knowing what one knows and doesn't know – is characterized by a student's ability to self-monitor levels of understanding. Self-regulation deals with a student modifying behavior in an effort to learn without direct teacher intervention. Metacognitive and self-regulatory practices aid significantly in student learning in science (NRC, 1999, 2005). Because successful inquiry practice in the classroom depends strongly upon individual student's abilities in these areas, teachers who promote metacognitive and self-regulatory practices are less likely to encounter resistance to inquiry-oriented instruction. While conducting individualized climate setting can be done with a whole class of students, the focus should be on individual cognition and accountability. Other individualized climate setting practices consist of promoting appropriate academic skills – from note taking to test taking. A teacher can help improve students' academic performance by making them more cognizant of the general procedures of "studenting." In order for students to be the best possible students they can be, teachers must have a comprehensive understanding of what it means to be both teacher and student. From the teaching perspective, a teacher should be certain to clarify objectives, motivate students, supply models, sequence subject matter appropriately, guide initial student trials, manage practice effectively, provide for recall, help students apply knowledge to new situations, and provide for self-assessment (Rhodes, 1992). The topics of metacognition and student self-regulation are addressed elsewhere, and readers are referred to key resources such as *How People Learn* (NRC, 1999), and *How Students Learn* (NRC, 2005).

Working with Non-Students

The inquiry-oriented teacher will at times be disappointed, and at other times dismayed, to learn that parents, administrators, and even teaching peers are resistant to inquiry practices. Climate setting can play a critical role when dealing with these individuals. It is preferred that climate setting be done in a proactive way, but sometimes – depending upon circumstances – only reactive climate setting can take place. Unfortunately, it is not at all unusual to find that parents, administrators, and peer teachers will concern themselves with pedagogical practices only after a "problem" is perceived.

Non-Students Generally: High school students who have been educated through the use of inquiry practices generally will be better prepared as college and university thinkers than will students who have merely memorized lot of facts and have learned how to do "plug and chug problem solving." Proponents of inquiry-oriented instruction should be prepared to point out that post-secondary faculty are aware of this fact. As a result, inquiry approaches are now being integrated into post-secondary instruction. College and university faculty members are more interested in students who know how to think than in students who know lots of facts. Research by Sadler & Tai (1997) dealing with the performance in introductory physics courses for almost 2000 students at 19 colleges and universities in the United States shows the value of inquiry-oriented high school instruction on post-secondary performance. Sadler and Tai noted that a smaller number of topics covered with increased depth of study leads to significantly higher grades in college physics courses. This approach is typical of inquiry-oriented instruction. An examination of compilations of posts to the Modeling Listserv at the Arizona State University Modeling Instruction website** (see High School Preparation for College) suggests that Modeling as an inquiry-oriented form of instruction really does better prepare high school students for post-secondary education. As Vesenka et al. (2000) point out, there is a growing recognition among higher education faculty that inquiry-oriented instruction such as the Modeling Method improves the level of performance in the areas of critical thinking and problem solving. As a result of these and similar findings, more and more high schools, colleges, and universities are turning to this mode of instruction. This paradigm shift in secondary and post-secondary instruction has been well documented on physics education research group web sites such as those at the University of Washington (McDermott, 2005), State University of New York-Buffalo

(MacIsaac, 2005), University of Maryland (Redish, 2005), and the University of Maine (Wittmann & Thomson, 2005) among others.

Parents: It is best to communicate with parents in advance about the inquiry-oriented teaching approaches to be used with their children. Open houses at the start of the school year are particularly valuable for allowing teachers to frankly address potential concerns related to inquiry. For instance, parents wonder how inquiry – while moving much more slowly than direct instruction – will adequately prepare students to successfully complete standardized tests. The point can be made that many standardized tests such as the ACT exam are not content tests; rather, they are tests that stress critical thinking skills and the ability to read and interpret graphs. Less structured open house nights might allow for involving parents in a short paradigm lab activity in which they can experience the fun of inquiry. Teachers might also want to post to their websites information that frankly addresses their concerns, and "making the case for inquiry."

Administrators and Peer Teachers: Every administrator and peer science teacher should be aware – or made aware of – the many substantive arguments in favor of inquiry so that they can understand or respond to criticisms of inquiry-oriented approaches. In order to prevent, offset, deflect, or defeat complains about inquiry stemming from those both inside and outside the classroom, practitioners of inquiry must be able to make the case for inquiry.

Making the Case for Inquiry

Whether or not teachers are climate setting proactively or reactively, knowledge of how to make the case for inquiry is critical for the inquiry-oriented teacher. The points below stem from such diverse sources as Francis Bacon's *Novum Organum* of 1620 (Anderson, 1985), *Goals of the Introductory Physics Laboratory* (AAPT, 1998), and *Inquiry and the National Science Education Standards* (NRC, 2000). Among the key philosophical arguments and research-based claims that can be made in favor of inquiry-oriented instruction are the following:

Through inquiry-oriented instruction students learn about science as both process and product. Understanding science consists of more than just knowing facts. An authentic science education will help students understand what is known as well as how it is known. Like the first true scientists, we reject Aristotelian scholasticism that would have us learn on the basis of the authority of others rather than from scientific observations, experiments, and critical thinking. Properly constructed inquiry-oriented laboratory activities that include some experience designing investigations engage students in important hands-on, minds-on experiences with experimental processes. As with any well-rounded education, we should seek to teach our students how to learn and think rather than merely what to think.

Through inquiry-oriented instruction students learn to construct an accurate knowledge base by dialoguing. Regardless of the type of classroom instruction, a student will build new knowledge and understanding on what is already known and believed. A student does not enter the classroom as a *tabula rasa* – a blank slate – as philosopher John Locke first suggested. Rather, students come to a classroom with preconceived notions, not all of which are correct. In the inquiry-based classroom, students formulate new knowledge by modifying and refining their current understanding and by adding new concepts to what they already know. In an inquiry-oriented classroom, the quality of classroom discourse is dramatically improved with the use of such things as whiteboards and Socratic dialogues. Teachers conducting Socratic dialogues come to understand what students know, and can identify, confront, and resolve preconceptions that limit students' understanding.

Through inquiry-oriented instruction students learn science with considerable understanding. Rather that merely memorizing the content of science only to be rapidly forgotten, students learning science through personal experience learn with increased conceptual understanding. Appropriate classroom and laboratory activities help students master basic science concepts. Experiential learning results in prolonged retention, and refines students' critical thinking and problem-solving skills helping them improve standardized test scores. A deep understanding of subject matter is critical to the ability to apply knowledge to new situations. The ability to transfer learning to new situations is strongly influenced by the extent to which students learn with understanding. Learning via inquiry is learning that lasts, and not learning that merely suffices for the demands of schooling.

Through inquiry-oriented instruction students learn that science is a dynamic, cooperative, and accumulative process. The work of scientists is mediated by the social environment in which they interact with others; the same is true in the inquiry-oriented classroom. Directly experiencing natural phenomena and discussing results helps students understand that science is the work of a community of real people, and that in science "genius" doesn't always matter - great progress can be made following the accumulation of many small steps. While the process of inquiry is slower than direct instruction, with its sometimes non-linear approach (allowing for the detection and correction of mistakes) it is more realistic and gives a better understanding to students of the social context of science. Only in cooperative settings such as laboratory work can students develop collaborative learning skills that are critical to the success of so many real world endeavors.

Through inquiry-oriented instruction students learn the content and values of science by working like scientists. The way we educate our students has profound implications for the future. We can encourage them to show submission of intellect and will thereby becoming uncritical consumers of information, or we can help them learn the nature and values of science by having them work like scientists gaining a scientific worldview. Don't we want to graduate students who are rational and skeptical inquirers rather than intellectual plebiscites? A great deal of introductory-level student learning should come directly from experience. The inquiry approach avoids presumptive authority, and inculcates students with a healthy skepticism. Inquiry-oriented instruction helps students confront the new age of intellectual barbarism by arming them with the skeptical, rational philosophy of Bayle, Bacon, Pascal, Descartes, and Locke.

Through inquiry-oriented instruction students learn about the nature of science and scientific knowledge. Students come to know how scientists know what they know. They learn to adopt a scientific epistemology. Students are moved from mere uncritical belief to an informed understanding based on experience. Inquiry-oriented instruction helps students to understand the role of direct observation, and to distinguish between inferences based on theory and on the outcomes of experiments. Inquiry-oriented laboratory work helps students develop a broad array of basic tools of experimental science and data analysis, as well as the intellectual skills of critical thinking and problem solving. Students learn to use nature itself as the final arbiter of claims.

Critical Need for Climate Setting

Forms of inquiry-oriented instruction such as the Modeling Method, cooperative learning, and problem-based learning, are all subject to various types, degrees, and frequencies of resistance from students, parents, administrators, and teaching colleagues who do not understand the value of inquiry. Even the teacher of inquiry can lose heart and begin to question whether or not inquiry is worth it upon encountering signficant resistance if he or she is unaware of the case that can be made for inquiry. Teachers employing these methods, therefore, have a critical need to understand the value of inquiry, and an ability to conduct climate setting.

During the three-week summer session of the *Chicago ITQ Science Project,* participants' attention was drawn to the need for conducting climate setting to offset resistance to inquiry. However, the importance and procedures of climate setting and classroom, school, and community atmosphere were neither sufficiently stressed nor properly appreciated. It was only through the autumn follow-up sessions with participants that it became clear that not enough time and attention were focused on this aspect of inquiry teaching during the summer workshop. As the work of the *Chicago ITQ Science Project* continues, teachers will be encouraged to regularly perform climate setting to help students and others understand how and why inquiry-oriented instruction is different from traditional didactic instruction.

Encountering resistance is relatively common among teachers who employ inquiry-oriented instruction. Fortunately, the resistance typically encountered by our teachers has been neither frequent nor strident. Resistance to inquiry eventually dissipates as students, parents, administrators, and peer teachers gain an understanding of the value of the various inquiry-oriented approaches employed. The importance of climate setting cannot be over emphasized in minimizing resistance to inquiry-oriented science instruction.

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References:

American Association of Physics Teachers (1998). Goals of the Introductory Physics Laboratory. *American Journal of Physics, 66*(6), June 1998, pp. 483-485.

Anderson, F.H. (1985). *The New Organon.* New York: Macmillan.

Johnson, D., Johnson, R. & Holubek, E. (1988). *Circles of Learning: Cooperation in the Classroom.* Edina, MN: Interaction Book Company.

Ledlow, S. (1999). Tips for Climate Setting in Cooperative Learning Classrooms. Available online: http://www.public.asu.edu/~ledlow/sledlow/climate.htm

MacIsaac, D. (2005). PhysicsEd. Buffalo State. Available: http://physicsed.buffalostate.edu/

McDermott, L. (2005). University of Washington Physics Education Group. Available online at: http://www.phys.washington.edu/groups/peg/

National Research Council (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

National Research Council (1999). *How People Learn: Brain, Mind, Experience, and School.* John D. Bransford, Ann L. Brown, and Rodney R. Cocking, editors; Committee on Developments in the Science of Learning, Commission on Behavioral and Social Sciences and Education, Washington, DC: National Academy Press.

National Research Council, (2000). *Inquiry and the National Science Education Standards.* Washington, DC: National Academy Press.

National Research Council (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* M. Suzanne Donovan and John D. Bransford, Editors; Committee on How People Learn, A Targeted Report for Teachers, Washington, DC: National Academy Press.

Redish, E.F. (2005). University of Maryland Physics Education Research Group. Available: http://www.physics.umd.edu/perg/

Rhodes, D. (1992). Basic Conditions for Learning. Unpublished manuscript.

Roth, D. (2003). PBL Climate Setting. Problem-Based Learning Workshop. Illinois State University, Normal, IL. June 9-13.

Sadler, P.M. & Tai, R.H. (1997). Success in college physics: The role of high school preparation. *The Physics Teacher,* 35, 282-285.

Vesenka, J., Beach, P., Munoz, G., Judd, F. & Key, R. (2000). A comparison between traditional and "modeling" approaches to undergraduate physics instruction at two universities with implications for improving physics teacher preparation. *Journal of Physics Teacher Education Online, 1*(1), 3-7.

Wittmann, M.C. & Thomson, J.R. (2005). University of Maine Physics Education Research Laboratory. Available: http://perlnet.umaine.edu/

