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# J P T E O

## INSIDE THIS ISSUE

### **1** Finally Arrived?

*Editorial*

### **3** Seeing is believing: Classroom demonstrations as scientific inquiry.

*Jerod L. Gross*

### **7** A multiple case study of novice and expert problem solving in kinematics with implications for physics teacher preparation.

*Carl J. Wenning*

### **15** Pre student teaching clinical experience guidelines for physics teacher candidates at Illinois State University.

*Carl J. Wenning*

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## *Finally Arrived?*

In early December, a few weeks before winter break here at Illinois State University, I told my department chairperson, "Well, I've been working continuously for eight years to get this physics teacher education program in shape. I think that I've done it. We have finally arrived." Do we as teacher educators every really reach the end of our journey to prepare the best teacher education programs possible? For a short time I thought that this might have been the case. It was really a case of wishful thinking on my part because within a few days new ideas presented themselves for improving my capstone Physics "methods" courses, Physics 312 -- *Physics Teaching from the Historical Perspective*.

Two ideas had been nagging me for a couple of months. First, how can we get our students to transfer their knowledge, skills, and experiences into actual inquiry-oriented high school teaching and, second, how can I best help them to make this transition? Now, a month later (I write this in later January 2003) and several weeks into this course I have come to realize that I stumbled onto something that has made a very big difference in the way I teach Physics 312. Previously I had taught the course from more of a history course perspective, rather than as a science methods course designed to help my students understand physics from a historical perspective. I chose to recreate this course as a series of minilabs, whereby students would be given several *inquiry-oriented student performance objectives* that they would translate into historical lab activities. Let me tell you how this now works, and about the results to date.

Prior to each class I present students with a pertinent historical reading. In this example, an article written by Thomas Young who was concerned about the appropriate mathematical representation of kinetic energy. In his 1801 talk, "Energy," presented to the "Royal Institution," Young noted how he had approached this problem experimentally. He allowed balls of varying mass but of the same size to fall from various heights into a box filled with tallow. He then measured the amount of volume hallowed out by the falling ball and related this to the mass and impact speed of the falling balls. He assumed that the volume of the hole so created was proportional to the energy required to produce it. He correctly concluded from his study that kinetic energy was proportional to mass and velocity squared.

After our class discussed this paper, I set the challenge before them in the form of an inquiry-oriented student performance objective, "Students will determine the empirical relationship between kinetic energy, mass, and velocity." The students quickly set to work dropping balls onto a flat slab of clay. They determined the volumes of the impressions made in clay by using an eye dropper to fill the voids with a number of drops. The number of drops, they reasoned, was proportional to the volume. Like Young, they were able to conclude that kinetic energy is proportional to mass and velocity squared. The students were stunned with the precision of the results, as was I. While many teacher candidates can state that kinetic energy equals  $(1/2)mv^2$ , very few know why. My students clearly do. We have subsequently performed many other lab activities each during each 2.5 hour class period using similar approaches, and the teacher candidates report that these inquiry-oriented activities are just what they need to guide and improve their own classroom teaching. If you'd like to see these many student performance objectives and how I have reformulated Physics 312, then please access the course web page and hyperlinks at: [www.phy.ilstu.edu/pte.html](http://www.phy.ilstu.edu/pte.html).

So, have I finally arrived? I suspect not. Every time I think that I've finally gotten things to be the way I want them, I find that there's a newer, better way to teach and to prepare teacher candidates. I have chosen to share this little vignette with you in the hope that you will consider sharing your own success stories. The readership of *JPTEO* is anxious to hear about new ways of preparing teacher candidates. We are all on the lookout of new strategies, so don't be reticent to share even simple things. Don't be intimidated by the longer research-based articles that appear here from time to time. Shorter articles showing the result of action research are equally welcome. I have included one of these "action research" articles at the end of this issue to give you some sense of the things that you might submit to enhance physics teacher education.

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Creating and maintaining any sort of journal requires a commitment from its readership to submit articles of interest and worth in a timely fashion. Without such contributions, any journal is bound to fail. It is hoped that *JPTEO* becomes a forum of lively exchange. It will become so only to the extent that its readers will submitting articles for consideration and publication. Detailed information about contributing to *JPTEO* can be found on the journal's web site at [www.phy.ilstu.edu/jpteo](http://www.phy.ilstu.edu/jpteo).

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# Seeing is believing: Classroom demonstrations as scientific inquiry.

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Demonstrations are a familiar component of any high school physics classroom. There are numerous ways in which effective demonstrations can increase student learning and support the process of scientific inquiry. Conversely, a poorly executed demonstration can leave students confused, misled, or even bored. A practical list of do's and don'ts is included to help all teachers insure that the power of demonstrations in the classroom is not squandered.

## The Power of a Demonstration

Mr. Rodriguez and Ms. Chan both use demonstrations regularly in their high school physics classes. Today they are both using a simple marble launcher assembly with two metal marbles to demonstrate that a projectile launched horizontally will hit the floor at exactly the same time as an object in free fall, assuming the two objects were put in motion at the same time from the same height above the floor. Ms. Chan enthusiastically explains the set up of the demonstration as she loads the marbles into the launcher. She asks her students for predictions of which marble will hit the floor first and why. She does not provide them with the answer ahead of time, but rather allows a short, spirited debate before triggering the launcher to settle the issue for her excited students. At the same time in a different classroom, Mr. Rodriguez explains to his students that since the horizontal and vertical motions of a projectile are independent, the two marbles will hit simultaneously. He then triggers the launcher, which he had loaded before class. The students watch with mild interest as the marbles hit the floor simultaneously. When Mr. Rodriguez asks for questions there are none, and he continues his lesson.

Both teachers used the same demonstration to explain the independence of horizontal and vertical motions of a projectile. Yet Ms. Chan's students are eager and engaged, while Mr. Rodriguez's students are hardly paying attention. By the next day, it is safe to assume that Ms. Chan's students will be able explain the physics principle at work, while Mr. Rodriguez's students will probably barely even remember the demonstration.

It seems clear that effective demonstrations can have a powerful effect on the student learning process. But what exactly are those effects, and are they worth pursuing? How are they aligned with National Science Education Standards (NSES), if at all? And what are some simple guidelines that can be used to increase the effectiveness of any teacher's classroom demonstrations?

## Demonstrations As Inquiry

It may not be immediately obvious how demonstrations are tied into scientific inquiry. After all, the picture of scientific inquiry presented in the NSES brings to mind students performing experiments and collecting data. That seems to be diametrically

opposed to the idea of students watching a teacher perform a demonstration. However, in this paper demonstrations are not being proposed as a substitute for relevant student laboratory experiences. Rather, demonstrations can be used as part of an overarching pedagogy that supports inquiry by requiring students to be actively engaged during demonstrations, instead of merely audience members seeking entertainment.

The NSES definition of scientific inquiry is comprised of two components: a set of "fundamental abilities" and a set of "fundamental understandings". In the next two sections of this paper, the fundamental abilities and understandings of inquiry are taken from Inquiry and the National Science Education Standards (NRC, 2000, pg. 165-167, 170-171), and are presented in italics. Following each ability and understanding of inquiry is my commentary on how they can be promoted by the use of demonstrations.

## Fundamental Abilities of Inquiry from NSES

1. Identify questions and concepts that guide scientific investigations. Demonstrations can be used to prompt student questions about the physical principles on display. This is particularly true when a demonstration taps into a commonly held student misconception. For example, the marble launcher used by Ms. Chan and Mr. Rodriguez intrigues the students with the unexpected result that both marbles strike the floor simultaneously. Using words alone is too often inadequate to present to students a clear picture of the physical phenomena in question. Instead, students need to see the principles in action. This will root the student's understanding of physics in his own sensory experiences, rather than the authoritative voice of the teacher.

2. Design and conduct scientific investigations. Demonstrations can be used to show how various pieces of scientific equipment and apparatus function. This can plant seeds in the students' minds regarding the equipment they would need to conduct their own investigations. Demonstrations also allow the teacher to model how a scientist conducts experiments. Students need to see the teacher progressing through the steps such as setting up and calibrating the equipment, collecting data, and troubleshooting when something goes awry.

3. Use of technology and mathematics to improve investigations and communications. Students should be expected to collect and use data from a teacher-led demonstration. Mathematical relationships between variables can be explored using the data as supporting evidence. Furthermore, doing both a low-tech and a high-tech version of a demonstration can show the effect of technology in scientific investigations, and then comparing the precision of the data collected, for example. Students may be surprised to discover that from time to time the low-tech “tried and true” methods are just as powerful as the newer high-tech methods.

4. Formulate and revise scientific explanations and models using logic and evidence. Recognize and analyze alternative explanations and models. Communicate and defend a scientific argument. As stated above, students should collect data from demonstrations as often as possible. These data can be used to support physical relationships that have already been derived in class. Alternatively, it can be used as the basis for deriving a previously unseen relationship. It can even be used to contradict a previously introduced relationship by introducing new variables to the situation. Whatever models are created or revised, students will have in hand the data to support and defend their conclusions.

#### **Fundamental Understandings of Inquiry from NSES**

1. Scientists usually inquire about how physical, living, or designed systems function. Demonstrations that can be used in a physics class to show how physical or mechanical systems function is limited only by the creativity the teacher.

2. Scientists conduct investigations for a variety of reasons. Demonstrations can be used at the beginning of a unit to pique the students’ interest in a new phenomenon, just like a scientist has his curiosity around by observing something heretofore unseen. Demonstrations can be used to confirm a previously taught concept, or to show an exception to a rule. This is analogous to a scientist performing additional experiments to confirm or to challenge his working hypothesis.

3. Scientists rely on technology to enhance the gathering and manipulation of data. Mathematics is essential to scientific inquiry. As stated previously, demonstrations in the classroom not only illustrate principles of physics, but also allow students to see various scientific instruments and techniques in action. Collection and analysis of data from a demonstration shows the interplay between math and science, and is vital in order to prevent the demonstrations from becoming merely a show for the students.

5. Scientific explanations must adhere to criteria such as being logically consistent, abiding by the rules of evidence, being open to questions and possible modifications, and being based in historical and current scientific knowledge. Teachers should ask thought-provoking questions based on the results of the debate, and should encourage spirited discussion of the new ideas that will emerge from the students. Student misconceptions are both numerous and deeply held. The experience of a demonstration can force to students to confront their closely held beliefs with the new evidence of their own sensory experiences.

Therefore teachers need to be aware of common student misconceptions, and should plan meaningful experiences, including demonstrations, to revise them.

6. Results of scientific inquiry – new knowledge and new methods – emerge from different types of investigations and public communication among scientists. The use of demonstrations as a source of real experimental data and a source of classroom discussion material will promote new understandings of physics in the students.

#### **Do’s And Don’ts of Demonstrations**

Clearly there is a strong pedagogical argument to be made in favor of using demonstrations in the classroom. However, if the demonstration is going to achieve any of the lofty aims of the NSES already described, it must be carried out effectively. Here are some guidelines that can be used to increase the effectiveness of any teacher’s demonstrations.

Be prepared. This sounds so elementary, yet it is so easy to overlook. First, the teacher should have a thorough knowledge of the physics principles being demonstrated. Teachers should not attempt to teach what they do not know. Demonstrations should be practiced ahead of time to assure smooth execution in class. A teacher who fumbles about trying to operate the equipment not only looks incompetent, but also runs the very real risk of completely obscuring the point of the demonstration altogether. Being prepared also requires that all of the necessary materials be on hand and functioning properly when class begins. It may be useful to keep a notebook with notes about each demonstration, how to set it up, typical problems encountered, typical student misconceptions, and a record of values that produced good results.

Do not be afraid of failure. Science is not a simple endeavor. Things frequently go wrong for practicing scientists, so teachers should be prepared for that same eventuality. The risk of failure can certainly be mitigated by proper preparation, but it is inevitable that even the most familiar demonstration will go wrong from time to time. Teachers should use these teachable moments to demonstrate how real scientists solve their problems by methodically examining and testing the setup. Teachers should explain to the class what they are checking and why, in order to help students understand the troubleshooting process.

Make the demonstration visible. If students cannot see a demonstration, then they are missing out on an important learning opportunity. Use of proper lighting and contrasting colors, clearing away all unnecessary items from the work area, choosing larger objects over smaller ones, and even elevating the equipment can all improve the visibility of the demonstration. Teachers should take care not to stand in front of the equipment to the maximum extent feasible. Finally, it may be advantageous to allow students to get out of their seats and to gather around the work area, as safety dictates.

Present real science, not a sideshow. Demonstrations serve serious educational purposes. They should not be presented as mere entertainment. This is not to suggest, however, that teachers should not be enthusiastic and engaging. Rather, avoid

demonstrations that detract from the class; for example, avoid performing demonstrations of physical principles that will not be taught at some time during the semester. Do not try to fool the students with tricks in the demonstration. The material in a physics class is challenging enough without resorting to tricks, which can result in student misconceptions as well as mistrust of the teacher. Whenever possible, use demonstrations to obtain some kind of quantitative results, even if they are rough. Always allow sufficient time to analyze and discuss the results of a demonstration. Again, a demonstration without an adequate explanation of the physics is simply entertainment.

Keep it as simple as necessary to make the point. The more complicated a demonstration is, the more time required to set up and execute, and the more chance of encountering problems during execution. Simpler setups allow for more class time to be devoted to analysis and discussion. Furthermore, students may be unable to follow a complicated demonstration. Teachers should carefully consider using students as assistants in the execution of a demonstration. Teachers should have the expertise with the equipment and should be able to perform the demonstration smoothly. Due to their inexperience, a student assistant may make procedural errors that can detract from the central purpose of the demonstration. Using computer simulations as demonstrations can save on setup time and allow for easy repeatability. However, over-reliance on computer simulations may lessen the educational impact on the students. For example, a real-life demonstration with the marble launcher is more likely to be a significant, memorable learning experience for the students than simply watching a computer-generated demonstration of the same principle.

Safety: Keep students a safe distance away from all potentially dangerous demonstrations. Make sure the risk of performing a dangerous demonstration is worth the educative reward for the students. If feasible, perform such demonstrations outdoors. Always keep first aid kits, fire extinguishers, and other

safety items close at hand, and show students where they are kept. Teachers should always be a model of laboratory safety by wearing, when necessary, appropriate clothing such as lab aprons, work boots, and goggles. Teachers should avoid wearing dangling ties or jewelry when performing demonstrations.

Demonstration evaluation: The demonstration rubric on page 6 was developed by the Physics Teacher Education program of the Physics Department at Illinois State University. It can be a useful tool for evaluating the execution of a demonstration. It is not designed for use by the high school students, however. It is intended for faculty members, administration, student teachers, and other teaching professionals.

### Concluding Thoughts

It should be self evident at this point that Mr. Rodriguez, the physics teacher from the introduction, has clearly wasted a golden opportunity for student learning by using poor teaching practices with his demonstrations. Properly used, demonstrations can be a meaningful part of any teacher's curriculum and can support the vision of science education extolled in the National Science Education Standards.

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Demonstrator: \_\_\_\_\_

Evaluator: \_\_\_\_\_

**Demonstration Rubric**



<b>Standard</b>	<b><i>Accomplished (3 pts)</i></b>	<b><i>Proficient (2 pts)</i></b>	<b><i>Basic (1 pt)</i></b>	<b><i>Unacceptable (0 pts)</i></b>
<b>Preparation</b>	Everything in working order, in place or readily accessible; evidence of rehearsal; high quality drawing or handout provided.	Most things work well; one or two minor deficiencies; clear evidence of rehearsal, but lacks finesse; good quality drawing or handout provided.	Things don't work well or flow smoothly; one or two things out of place or missing; only fair quality drawing or handout.	Things are not in working order; demonstration fails; no evidence of rehearsal or adequate preparation; low quality drawing / handout or missing.
<b>Knowledge</b>	Demonstrates clear understanding of principle or concept involved; accurately relates concept to demonstration.	Exhibits only slightly limited understanding or principle demonstrated; minor inaccuracies in relating demonstration.	Exhibits somewhat limited understanding or principle demonstrated; minor inaccuracies in relating demonstration.	Lacks an understanding of the principle or concept demonstrated; inaccurately relates demonstration of principle or concept.
<b>Visibility</b>	Suitably large equipment, background taken into consideration; color added to liquids; adequate illumination; elevation to appropriate level; does not hide display with body.	Some demonstrations marginally adequate as far as visibility is concerned, others much better; those in front can see reasonably well, those in back have a hard time seeing some demos.	Demonstrations marginally adequate as far as visibility is concerned; those in front can see reasonably well, those in back have a hard time seeing.	Demonstrations hard to see for any number of reasons; no evidence of concern by presenter for visibility consideration.
<b>Simplicity</b>	Avoids unnecessary complexity (e.g., adjustments) and common place materials if possible.	Degree of complexity effectively only better students; others left somewhat confused.	Somewhat complex; the demonstration is not overly helpful making point or introducing concept.	Students "can't see the forest for the trees"; too complicated; concepts too difficult or not appropriate to demos.
<b>Suitability</b>	Demonstration employed is probably the best for demonstrating concept.	Demonstration adequate, but a better choice might have been made.	Poor connection between demonstration and concept or principle.	Insignificant connection between demonstration and concept of principle.
<b>Safety</b>	Safety goggles and/or protective screen used if appropriate; keeps students back; keeps first aid and other emergency equipment on hand.	Expresses some degree regard for safety of students, but makes fails to take adequate precautions to actually prevent possible minor harm to students.	Expresses some degree regard for safety of students, but makes fails to take adequate precautions to actually prevent possible major harm to students.	Shows positive disregard for student or own safety; fails to pass the test of foreseeability; shows negligence; threatens own or students' safety.
<b>Performance</b>	Employs mystery and showmanship; uses precise in technique.	Amusing if not totally captivating presentation; clear understanding of need to involve students.	Adequate presentation but nothing fancy; fails to engage or involve students.	Poor delivery style; inappropriate technique.
<b>Pedagogy</b>	Maximizes educational benefit of demonstration; gears demonstration toward students; greatly engages students intellectually; uses inquiry approaches.	Seek to maximize educational benefit of demonstration; but gears demonstration toward students' abilities and interests; somewhat didactic in delivery.	Attains moderate educational benefit from demonstration by playing to students; limited interaction with students.	Demonstration appears to have little or no educational value; bores students; students not intellectually engaged; essentially lectures.
<b>Engagement</b>	Students thoroughly engaged by demos, discussion & participation.	Students pay attention and even participate, but are not intellectually engaged.	Students lose attention; inconsistent intellectual & physical engagement.	Students not mentally or physically engaged in demonstration.
<b>Assessment</b>	Assesses student understanding by constant, thought-provoking questioning.	Does complete job of assessing student understanding, but does so only at end of demo.	Does incomplete job of assessing student understanding, or assesses only at end of demo.	Makes no attempt to assess student understanding.

# A multiple case study of novice and expert problem solving in kinematics with implications for physics teacher preparation.

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In recent years, physics education researchers and cognitive psychologists have turned their attention to the question of how individuals solve basic physics problems. The author summarizes the surprising results of a multiple case study in which three experts and three novices were observed as they solved kinematics problems using a “think aloud” protocol. Follow-up interviews and content analysis led the researcher to conclude that expert problem solvers do not always follow the most efficient routines, nor do they always use the most effective methods for teaching basic problem-solving skills to students. These circumstances have important implications for physics teacher education.

The college-level, algebra-based physics class began with the instructor asking the students if they had any questions about the kinematics homework problems that they were supposed to have attempted the night before. A discussion dealing with three homework problems (and one example problem) ensued for the next 45 minutes. While the instructor was solving these problems, the 40 or so students observed intently. The majority of the students listened while the instructor talked and worked on the board, yet about one third of the students ceaselessly recorded in their notebooks everything that the instructor wrote.

In each case of problem solving, the treatment by the instructor was consistent and methodical. The instructor began with a statement of the problem. Next, he drew a picture. Thirdly, he stated what was known or given as part of the problem. Fourth, he identified a principle by which the problem could be solved. Fifth, he stated the relevant equation that related the knowns and unknowns. Sixth he restated the knowns and unknowns. He then solved the equation for the required unknown, inserted the knowns, and carried out the arithmetic calculation. The instructor then made reference to checking the answer for reasonableness. The instructor’s approach to the problems seemed clear and, yet, something seemed to be missing. During the problem-solving session there were 19 questions asked by students. The questions, interestingly enough, more frequently dealt with problem-solving processes (“How do you know when to...?” and “What do you do if...?” and “How do you go about...?”) than any thing else.

Then, the instructor moved on to a 20-minute lecture about Newton’s first and second laws. He did not provide many significant real-life examples of the first law, and the second law was treated entirely at a theoretical level. During this time, all students appeared to be diligently taking notes. At the outset of the lecture portion of the class, the instructor dealt momentarily with the alternative conception that moving things need a constant force to keep them in motion.

At the end of this session, and near the end of the class, the instructor worked another example problem. He assigned 16 exercises for homework at the end of the hour. Eight of the

exercises were questions, six were “standard” problems, and two were “challenge” problems. The students diligently recorded the list of required homework problems. Another typical introductory physics class had come and gone.

What do we leave students with at the end of a series of such introductory physics lessons? Are students better able to solve physics problems now that they have seen a few examples? Do they have a metacognitive understanding of this simple problem-solving process that is so frequently tendered with almost every lecture-based recitation class in which problem solving is addressed? Do courses that have as their greatest emphasis the solution of textbook problems leave the students with the perception that the scientific process is little more than searching for the right equation? How important are concrete examples to true student understanding of physical phenomena? These are only a few of the questions that might arise from intently watching and seriously reflecting on what happens in many introductory physics classes. To focus on all these questions would be too great a task in the limited space available for this article and, so, a more narrow view will be centered on the difficulties associated with teaching the general problem-solving paradigm so frequently taught in didactic introductory-level physics courses – find the knowns and unknowns, state the relationship between them, and solve for the unknown.

## Problem Solving in Physics

In recent years physics education researchers and cognitive psychologists have turned their attention to the question of how individuals solve physics problems (Newell & Simon, 1972; Chase & Simon, 1973; Simon, 1978; Larkin, McDermott, Simon & Simon, 1980; Chi et al., 1981; Langley et al., 1987; Heller, Rieman & Chi, 1989; Heller, Keith & Anderson, 1992). This case study research has focused on two areas as they pertain to physics problem solving: (a) the overall plan of attack used to solve problems, and (b) the identification and use of heuristics in problem solving. The researchers generally approach a study of the first focus area by comparing and contrasting the

performance of novices (generally defined to be students in introductory physics classes) with that of experts (generally defined to be physics teachers). Studies in the area of problem solving frequently utilize qualitative approaches and involve a relatively small number of subjects. "Think-aloud" protocols are normally used in these efforts.

A clear and concise definition of problem solving must be given if the problem statement is to be meaningful. There are a number of definitions of the word "problem," but the definition that is most apropos to this project is a characterization - work associated with those tasks found at the end of chapters of introductory physics text books. Typically, these tasks involve a statement of information and/or circumstances, and an additional variable or variables are determined on the basis of the information provided. These tasks tend to be very specific and the work and goal well defined. Problem solving then is the process of attaining the goal of any specified problem.

### Study Context

Studies of novice and expert physics problem solvers have suggested that there are two distinct and contrasting patterns of problem solving among experts and novices. These variations have led to the formulation of two major models for problem solving. According to Larkin et al. (1980), expert problem solving is typified by the KD model, the so-called knowledge-development approach. Novice problem solving is typified by the ME model, the so-called means-end approach. In the ME model the student typically works "backward" from the unknown to the given information. Under this scenario the novice problem solver (NPS) essentially writes an equation and then associates each term in the equation with a value from the problem. If there are additional unknowns, the problem solver moves on to the next equation. In the KD model the expert proceeds in the opposite direction, working forward from the given information. Under this second scenario, the expert problem solver (EPS) associates each of the knowns with each term of the equation as the equation is set up. That is, novices move from equations to variables, while the experts move from the variables to the equation.

The research in the area of physics problem solving accelerated rapidly in the early 1980's and is now the focus of attention in the research literature. There are a number of questions left unresolved, including those given by Maloney (1994), "What knowledge do novices typically use when faced with physics problems?" and "How is the knowledge that a novice possesses organized in memory?" and "How do alternative conceptions affect novices' representations?" However important these questions, the basis of this research still depends upon the answer to the question, "*How do problem-solving approaches differ between novices and experts?*"

### Case Study Method

In case studies, the researcher is the primary research instrument. When this is the case, validity and reliability concerns

can arise. The human investigator may misinterpret or hear only certain comments. Guba and Lincoln (1981), as well as Merriam (1991), concede that this is a problem with case study work. Yin (1994, p. 56) lists six attributes that an investigator must possess to minimize problems with validity and reliability associated with the use of the human research instrument.

- A person should be able to ask good questions - and to interpret the answers.
- A person should be a good "listener" and not be trapped by his or her own ideologies or preconceptions.
- A person should be adaptive and flexible, so that newly encountered situations can be seen as opportunities, not threats.
- A person must have a firm grasp of the issues being studied, whether this is a theoretical or policy orientation, even if in an exploratory mode. Such a grasp focuses the relevant events and information to be sought to manageable proportions.
- A person should be unbiased by preconceived notions, including those derived from theory. Thus a person should be sensitive and responsive to contradictory evidence.

The researcher believes that he exhibited these personal characteristics, though "no devices exist for assessing case study skills." (Yin, 1994, p. 56)

Five kinematics physics problems were written for this project. The five questions ranged from simple one-step problems with a single output variable, to more complex two-step problems where more than one output variable was requested. The problems used in this study can be found in Appendix A.

Three faculty members (with an average of about 9 years of university-level teaching experience) and four students were then self-selected to participate in this study. All faculty members were male; one of four physics students was female. Though this may at first appear to be too large a sample for a case study, "any finding or conclusion in a case study is likely to be much more convincing and accurate if it is based on several different sources of information." (Yin, 1994, p. 92) The problem-solving skills of these individuals were examined through observation, interview, and content analysis. Such use of multiple data sources also enhances validity and reliability via triangulation.

All volunteer faculty members participating in this study had experience teaching introductory physics courses for non-majors. All students were volunteers who were currently enrolled in an introductory, algebra-based physics course for non-majors at a middle-sized Midwestern university. Students were informed that a wide range of problem-solving abilities were needed, and that excellence in problem solving was not a prerequisite for participating in the study. (The female student was subsequently dropped from the study due to an apparent lack of ability to solve even rudimentary algebraic equations.)

Three data collection strategies were used in this project. Participants first solved the five physics problems using a “think aloud” protocol. The researcher listened to the problem solvers, recording pertinent details dealing with the solution of the problems. He later coded these comments for analysis. Following problem solving, the researcher collected the written work which would be used in content analysis, and then commenced a semi-structured interview to achieve a greater understanding of the problem-solving process. In follow-up interviews, faculty members were asked three questions common to all study participants, and two additional questions reserved to expert problem solvers. Students were asked the same three common questions and three additional student-specific questions. The questions can be found in Appendix B.

### Findings from Observations

Appendix C shows the coding plan for problem solver statements made while working on the problems using a think aloud protocol. The coding plan consists of steps in a theoretical scheme of problem solving enunciated by Heller, Keith, and Anderson (1992), and modified and extended slightly for this study. Each step of the problem-solving process is operationally defined with descriptors. For instance, a problem solver can be said to be visualizing the problem if he or she draws a sketch, identifies the known variables and constraints, restates the question, or identifies the general approach to solving the problem. While problem solvers were working problem number one (and all subsequent problems), the researcher recorded statements for later coding. The results of the coding can be found in Table 1.

Model	EPS #1	EPS #2	EPS #3	NPS #1	NPS #2	NPS #3
1	1	2	2	1	2	1
2	2	3	1	2	1	3
3	3	1	3	3	3	4
4	4	4	4	4	4	6
5	5	5	5		5	5
						7
						5
						3
						7
						3
						4
						5

Table 1. Logical approaches used by expert and novice problem solvers to solve problem one.

This table shows the logical approaches used by expert and novice problem solvers. If a problem solver uses what is theoretically the most efficient scheme for solving the problem, then his solution should consist of five sequential steps: 1, 2, 3, 4, and 5. If expert problems solvers (EPS’s) depart substantially and consistently from this model, it might lead the researcher to conclude one of two things: either these particular EPS’s are not very efficient, or the model proposed by Heller et al. is simply wrong.

The data tabulated in Table 1 shows that EPS’s do not generally follow the same paths to a solution as the theoretical

model. In all three cases, the EPS’s chose different routes to solve the problem. These paths were 123, 231, and 213. Novice problem solvers (NPS’s) #1 and #2 took similar mixed routes, while NPS #3 departed from the general problem solving model when he failed to include step two. Among the six problem solvers, this was the only person to neglect this step, leading possibly to the long, convoluted solution to the problem as indicted by the twelve steps. Interestingly enough, five of the six problems solvers made the effort to mentally check their answers for apparent correctness.

The overall impression gained by the researcher while observing the problem solvers was that the problem-solving procedures utilized by novice problem solvers are very unstructured and inefficient. Problems are not systematically approached, knowns are rarely written down in equation form (for instance,  $a = 1 \text{ m/s}^2$ ), starting equations are rarely written down, equations are not solved for unknown variables before inserting the knowns, work is done without units, solving algebraic equations appears to be a problem for most, etc. Students, in many cases, quite randomly choose equations to solve for the unknown. They, not infrequently, expected a calculator to “solve” the problem for them. One student in particular regularly multiplied and divided numbers in a random fashion looking for solutions that “looked right.” This procedure might work on a multiple-choice test - something that is normally used at the introductory level - but not in this research project where students had to derive precise answers of their own. In general, the time required for EPS’s to solve problems was one third that required by NPS’s.

### Findings from Interviews

It is clear from the interview process that in the area of kinematics, students tend to follow the same general procedures as the experts when it comes to problem solving: search for knowns and unknowns, establishing or finding a relationship between the knowns and unknowns, and then solve for the unknown. The general procedure for problem solving is shown in Figure 1. In some cases the students would check their answers to see if they made sense; this was normally the case with experts. Checking the answer generally took the form of looking at the magnitude and sign of the solved variable. The students interviewed seemed to be clear on the overall process. When they did have trouble, it was in selecting the appropriate equation to relate the known and unknown variables through the most direct route. In this procedure two faculty members were very efficient; however, one expert problem solver almost invariably started the problem-solving process with the same kinematics equation, no matter what the original given quantities were.

Two students were unable to explain clearly the “black box” procedure for selecting the appropriate kinematics equation to relate the variables (see Figure 1). For instance, “I look to fit all the information into a model” and “I see what formula gives me the information I need.” The result of this uncertainty was clearly evident as these two students randomly selected one equation after another in an effort to “plug and chug” their way through

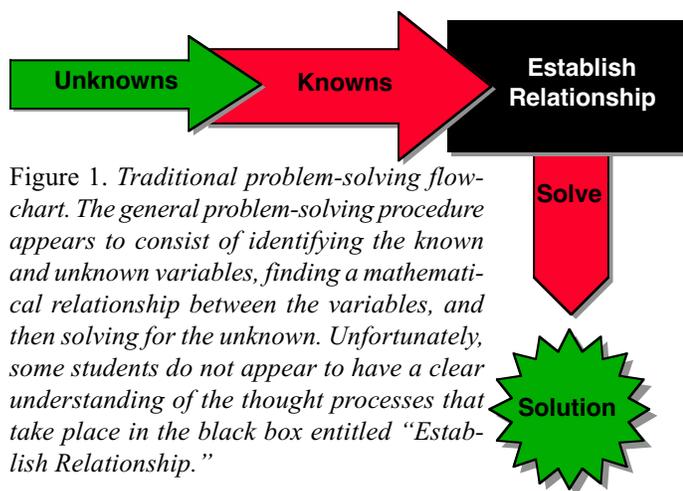


Figure 1. *Traditional problem-solving flow-chart. The general problem-solving procedure appears to consist of identifying the known and unknown variables, finding a mathematical relationship between the variables, and then solving for the unknown. Unfortunately, some students do not appear to have a clear understanding of the thought processes that take place in the black box entitled “Establish Relationship.”*

the problem set. One student was clear about the procedure, “The equation I would select would be that which has one unknown variable - the one you are looking for. Alternatively, using a formula with two unknowns where one of the unknowns can be obtained with the use of another formula.” All problem solvers, novices and experts alike, appeared to use the means-ends approach to solve the five physics programs provided.

The physics teachers were asked to explain how they taught kinematics problem solving in their introductory courses. In all cases teachers indicated that they made use of examples almost exclusively. In one case, an instructor noted that from time to time he would attempt to clarify the process by explaining the process in words; in another case an instructor indicated that he would never use a metacognitive approach. In his words, “...I do not discuss general strategies.... I’m not sure some students at this level can conceptualize general strategies. Strategies are drawn by example.” Another instructor noted, “I don’t think that there is any particular procedure that you can describe to the students for them to become more expert. In special areas I point out what they have to do to recognize the unknown, the data, and what sort of formula for them to use. Students often randomly search for formulas. I warn them against this.” In no case was any attempt made to explain explicitly what was going on in the mind of the instructor to explain the equation selection process.

The students interviewed mentioned that they did make use of examples to learn how to do kinematics problem solving. In all three cases the students reported reading over the example, and sometimes working the example, in an effort to comprehend the general procedure. They did not indicate using examples as templates for solving problems except in one instance. This student reportedly resorts to using examples like templates to find one variable in a two-step problem in which the desired variable is not immediately obtainable directly from an equation.

When queried, students expressed the opinion that they had learned general problem-solving strategies *prior* to taking the physics class mentioned in this study. One student attributed his physics problem-solving skill to a high school classmate; another to life experiences; and yet another to related course work in business classes. Students generally felt that their problem-

solving skills were enhanced by taking the physics course, and this helped them to gain a broader perspective on the problem-solving process. There was unanimous agreement among students that instructors did very little to help students learn the fundamental intellectual processes of mathematical problem solving in physics.

### Findings from Content Analysis

Subsequent to the follow-up interviews, the written work of problem solving was collected for content analysis. The procedures used by problem solvers were coded on the basis of equations used to find intermediate or final unknowns following the work of Simon and Simon (1978). The equations referred to are those appearing on the problem sheet shown in Appendix A. The first equation is labeled 1, the second 4, the third 5, the fourth 7, and the fifth 8. This numbering sequence was chosen to remain consistent with previous research on kinematics problem solving. The coding procedure is “shorthand” that indicates how problem solvers approached problems. For instance, if a problem solver found the average velocity,  $\bar{v}$ , using equation 5, then the approach was coded ( $\bar{v}$ -5). If the instantaneous velocity,  $v$ , was found from equation 5, then the approach was coded ( $v$ 5).

Table 2 shows the results of coding the mathematical steps used by EPS’s and NPS’s. The designations running horizontally along the top numerically distinguish EPS’s and NPS’s. The numbers running vertically along the left side of the table indicate problem number. Each cell contains the equation-based problem solving approach. False starts have not been included in this table, nor have unsuccessful attempts to solve problems. If a cell in the table is blank, it is an indication that the problems solver was unable to find the correct solution.

From an inspection of the approaches outlined in this table, it is clear that not all expert problem solvers determine unknowns in the same fashion or with the same efficiency (efficiency being defined as working toward the answer by taking the most direct route - using the fewest number of steps and equations to solve for an unknown). Admittedly, there are several ways to solve each of these problems, with some routes being different but equally efficient. This can be seen in the solution of problem 5 by expert problem solvers.

Differences in problem-solving efficiencies were notable among EPS’s attacking problem 4. For example, compare the procedure of EPS #2 with those used by EPS #1 and EPS #3. EPS #2 used a solution procedure that was less efficient than that used by other EPS’s. EPS #2 solved for the product of  $a$  and

#	EPS #1	EPS #2	EPS #3	NPS #1	NPS #2	NPS #3
1	$\bar{v}5 - a8 - t4$	$\bar{v}5 - a7 - t4$	$\bar{v}5 - a8 - t4$	$\bar{v}5 - t1$	$\bar{v}5 - t1$	$\bar{v}5 - t1$
2	$a4 - x7$	$a4 - x7$	$a4 - x7$			
3	$t4$	$t7$	$t4$		$t4$	$x8 - t7$
4	$a8$	$at4 - at4 / t7$	$a8$		$a8$	$a8$
5	$v8 - t4$	$t7 - v4$	$v8 - t4$	$t4^*$	$v8 - \bar{v}5 - t1$	$v8 - t4$

\* Did not solve for  $v$ .

Table 2. *Mathematical approaches used by expert and novice problem solvers.*

$t$  from equation 4, and then divided this product by  $t7$  while the other EPS's solved equation 4 directly. This appears to have do with EPS #2's propensity for beginning most problems with a statement of equation 7, and then searching for variables to insert into the equation - not always the most efficient procedure.

Interestingly, some NPS's exhibited what appears to be greater insight in solving some problems than EPS's. For instance, note how all NPS's solved problem 1 in a much more direct fashion than any EPS, not solving for acceleration ( $a$ ) in order to find  $t$ . Though the table does not show it, NPS's took a significant number of dead-end approaches to solving the problems.

## Discussion

The findings of this research project do not lend support to the claim that expert problem solvers tend to use a KD approach and novice problems solvers an ME approach - at least in the area of kinematics. Both NPS's and EPS's used the same technique of searching for an equation among a group of equations that contains the end variable. They then worked from this end using any means necessary. One might argue that there is no alternative to the solution of kinematics problems, but the contrasting solution of problem 1 by EPS's and NPS's would seem to indicate that the students interviewed have used a more "insightful" KE approach than did the EPS's.

It appears that the general procedure for solving kinematics problems (find the knowns and unknowns, state the relationship between them, and solve for the unknown) are clear to the students studied. It is also clear that these students have *not* learned detailed problem-solving procedures by watching instructors solve example problems. They seem to have done so on their own - in other courses or through friends. What students are not consistently clear about is how to select the appropriate kinematics equation or equations to relate and solve for the problems' unknown. Evidently some students have been unable to figure out by observation the relatively sophisticated black box mental process the instructor goes through to select the appropriate kinematics equation.

What was not self-evident to the physics instructors is that students would appear, in some cases, not have a good understanding of the equation-selecting process that goes on quickly in instructors' minds. Though instructors argue that students appear to learn from example, one of the most important examples that is lacking is that which illustrates the thinking process that the course instructor goes through to select the appropriate equation among those available in kinematics. In one case a NPS had a clearer view of this than, perhaps, an EPS. This same EPS noted that he didn't think there was a general problem-solving process that students could comprehend. Perhaps this is so because that EPS never established a clear procedure for himself as is evidenced by the rigid, lock-step procedure of attempting to solve the kinematics problems by starting with equation 7 each time.

It is clear from subsequent discussions with each of the faculty members participating in this project that they may well generally lack a clear understanding of students' problem-solving

difficulties. They tend to see a host of student problem-solving difficulties such as: (a) failing to use a systematic process to solve problems, (b) failure to identify variables with known quantities, (c) adding dissimilar knowns together such as velocity and acceleration, (d) trying to solve equations without writing them down, (e) using calculators to solve the problems rather than the equation for the unknown, (f) randomly selecting equations to be solved for the unknown variable, (g) making algebraic errors, (h) confusing average velocity with instantaneous velocity, (i) failing to recognize simplifying conditions (XXX at top of a vertical flight path for a projectile, for instance), and that (j) novices are much less systematic than experts in both thinking and writing down their work. The instructors studied do not seem to be aware, however, of the difficulties students face when attempting to figure out what is going on in the black box of establishing relationships between variables. How widespread this evident unawareness on behalf of instructors is not known.

Because the faculty members interviewed possibly have never taken the time to analyze student problem-solving difficulties, and then triangulated those observations to lend credibility to their findings, they seem not to be aware of the central issue of problem solving by NPS's. Additionally, if the instructors studied were to more closely examine the nature of the questions that so many students ask during class, they might be more aware of the need for students to have a metacognitive understanding of the problem-solving process being used, and particularly those occurring in the dark recesses of the black box known as "establish relationship."

Two questions that arose in the mind of the interviewer as he talked with students and faculty members alike were, "Why don't faculty members take the time to take a metacognitive approach to problem solving?" and "Why don't faculty members talk about the entire problem-solving rather than expecting students merely to learn by example?" If instructors were to clarify for themselves the most efficient approaches for solving problems, this might enhance their teaching and student problem solving as well. As a result, emphasis in the preparation of physics teacher candidates should be placed on the metacognitive processes involved in problem solving. It also bodes well for a structured problem-solving process. A more systematic analysis of an approach to problem-solving difficulties in all areas of physics teaching promises to pay dividends.

## Teacher Preparation

If traditional problem solving involving chapter problems is to serve as one of the central foci of physics teaching, then teacher educators need to educate teacher candidates to speak about problem solving metacognitively, thereby speeding up and clarifying the learning process as it relates to solving chapter problems. It appears as though the transfer of the problem-solving skill would be facilitated through the use of a more didactic approach that would directly address the "back box" component of problem solving that students are too often expected to solve "by example" when no example is actually provided. Students cannot directly observe the intellectual processes used by expert

problem solvers; they can only infer them. Teachers and teacher candidates also need to realize the incessant practice of the traditional problem-solving routine results in diminishing returns as far as learning the process is concerned. Direct, detailed instruction in the complete process of problem solving will allow classroom teachers to spend more time on developing other intellectual process skills important to a more comprehensive form of scientific literacy.

Too often other intellectual process skills that can be rightly expected of scientifically literate students are not being taught due to overemphasis on traditional problem-solving approaches. A pedagogy that focuses too much on solving textbook problems trivializes science and shows it to be so much a search for the right formula. Teachers at all levels need to understand that scientific literacy means more than being able to solve chapter problems in textbooks. Teachers need to realize that, if a student is to be scientifically literate, he or she must be capable of using not only rudimentary and integrated science process skills (Ostlund, 1992; Lawson, 1995; Rezba, Sprague & Fiel, 2003), but *enhanced science process skills* as well. Rudimentary science process skills are typically those to be developed in, say, elementary and middle school. Integrated science process skills, if taught at all, are taught in middle and high school (see Table 3). While most of the science reform movement literature has focused on these skills, it seems that even more a more advanced group scientific thinking skills are being overlooked. Enhanced science process skills truly define a scientifically literate person and are those skills that represent the end-goal of science education. Enhanced science process skills include the ability to:

- **solve complex, real-world problems.** Helping students to solve lifelike problems must be the fundamental reason of why we educate out students in the sciences and other disciplines.
- **establish basic empirical laws.** Student can, by collecting and graphically depicting and interpreting data, establish basic empirical laws.
- **synthesize theoretical explanations.** While not essentially different from hypothesizing, providing theoretical

explanations is done at a substantially more advanced level. It is a synthesis of scientific knowledge and mathematics to answer questions that might not be so readily determined via experimentation.

- **analyze and evaluate scientific arguments.** Includes breaking down arguments into their constituent parts, determining the accuracy of scientific statements, evaluating data and conclusions drawn from that data.
- **construct logical proofs.** Closely related to analysis and evaluation of scientific arguments, this process flows in the reverse and includes such things as developing complex arguments from their simpler parts, making scientifically accurate statements, interpreting and drawing conclusions from data.
- **generate principles through the process of induction.** Inductive processes are generally conceived of as moving from specific observations to their generalization in the statement of general principles based upon observations of specific cases.
- **generate predictions through the process of deduction:** Deductive processes are generally conceived of as moving from general statements of principle to generation of specific predictions based upon some form of underlying theory base.

Science teacher educators promoting inquiry practices among teacher candidates will want to do more than focus entirely upon the ability to solve textbook problems. Science is much more than this, and a variety of activities should be included in the school curriculum to help students develop enhanced science process skills.

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Rudimentary Process Skills	Integrated Process Skills
Observing	Identifying Variables
Communicating	Constructing a Table of Data
Classifying	Constructing a Graph
Measuring Metrically	Describing Relationships Between Variables
Inferring	Acquiring and Processing Data
Predicting	Analyzing Investigations
Decision Making 1	Constructing Hypotheses
<i>and according to some:</i>	Defining Variables Operationally
Estimating	Designing Investigations
Collecting Data	Experimenting
	Decision Making 2
	<i>and according to some:</i>
	Developing Models
	Controlling Variables

Table 3. Rudimentary and Integrated Intellectual Process Skills for Science

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## Appendix A

### *Think Aloud Physics Problems*

Please use a “think aloud” protocol as you solve the following problems. Use a separate sheet of paper for each problem. Clearly label each problem with the corresponding numbers below. A calculator is provided. Take the magnitude of the acceleration due to gravity ( $g$ ) to be equal to  $9.8 \text{ m/s}^2$ . Below are formulas for your use.

$$\bar{v} = \frac{x}{t}$$

$$v = v_o + at$$

$$\bar{v} = \frac{(v_o + v)}{2}$$

$$x = v_o t + \frac{1}{2} at^2$$

$$v^2 - v_o^2 = 2ax$$

where  $x$  is the distance traveled by an object during a time  $t$ , with constant acceleration  $a$ , initial speed  $v_o$ , final speed  $v$ , and average speed  $\bar{v}$ .

1. A bullet is shot from a rifle with a speed of 160 m/s. If the barrel of the gun is 0.8 m in length, what is the average speed of the bullet while in the barrel assuming constant acceleration? For how long is the bullet in the barrel?
2. A “dragster” accelerates uniformly from rest to 100 m/s in 10 s. How far does it go during this interval?
3. A toy rocket is shot straight upward from ground level with an initial speed of 49 m/s. How long does it take the rocket to return to earth? Assume the absence of air resistance.
4. A landing commercial airliner, upon “reversing” its engines, uniformly slows from 150 m/s to 30 m/s using 1,800 m of runway. What is the acceleration of the plane during this procedure?
5. A little girl glides down a long slide with a constant acceleration of  $1 \text{ m/s}^2$ . If the girl gives herself an initial speed of 0.5 m/s and the slide is 3 m long, what is her speed upon reaching the bottom of the slide? How long does it take her to reach the bottom of the slide?

## **Appendix B**

### *Interview Questions*

#### For novices and experts:

1. What is the first thing you search for in a problem statement?
2. What is the first thing you do after determining what you are to find?
3. Do you follow any particular pattern or procedures when you solve physics problems? If so, please explain.

#### For novices only:

4. When you have difficulties solving a physics homework problem, what do you do?
5. What use do you make of examples when attempting to solve problems with which you are having problems?
6. How did you learn to solve physics problems?

#### For experts only:

7. How do you teach your introductory physics students how to solve physics problems?
8. Do you ever talk about the problem-solving process? If so, what do you say?

## **Appendix C**

### *Coding Plan for Observations of Physics Problem Solving*

#### 1. Visualize the problem.

- draw a sketch
- identify the known variables and constraints
- restate the question
- identify the general approach to the problem

#### 2. Describe the problem in physics terms.

- use identified principles to construct idealized diagram
- symbolically specify the relevant known variables
- symbolically specify the target variable

#### 3. Plan a solution.

- start with the identified physics concepts and principles in equation form
- apply the principles systematically to each type of object or interaction
- add equations of restraint that specify any special conditions
- work backward from the target variable until you have determined that there is enough information to solve the problems
- specify the mathematical steps to solve the problem

#### 4. Execute the plan.

- use the rules of algebra to obtain an expression for the desired unknown variable
- instantiate the equation with specific values to obtain a solution
- solve the equation for the desired unknown

#### 5. Check and evaluate.

- check - is the solution complete?
- check - is the sign of the solution correct?
- check - does the solution have the correct units?
- check - is the magnitude of the answer reasonable?

#### 6. Makes an Error.

- makes error in solution of algebraic equation
- makes error in statement of fact

#### 7. Expresses Confusion.

- admits confusion
- expresses doubt
- expresses anger
- admits inability / gives up

# Pre student teaching clinical experience guidelines for physics teacher candidates at Illinois State University.

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Action research at Illinois State University has shown that pre student teacher clinical experiences are an excellent way to help teacher candidates make the transition to student teaching. The University's physics teacher education program has created a wide variety of clinical experience activities that each teacher candidate must complete at his or her future student teaching site during the five weeks immediately prior to the beginning of the practicum. These clinical experiences - talking frankly with the cooperating teacher, visiting with the school's conferral and referral personnel, and working with students - smooth the transitional process and allow the student teach to "hit the ground running" during their 10-week experience.

Physics teacher candidates at Illinois State University must complete 100 hours of clinical experiences prior to the student teaching semester. Because many of these clinical experiences often deal exclusively with pedagogy, additional clinical experiences are required of physics teacher candidates during the first five weeks of the student teaching semester to help candidates learn about some of the other practical aspects of teaching. The first five weeks of a student teacher's semester are spent on the University's campus taking two courses - Physics 312: *Physics Teaching from the Historical Perspective* and Physics 353: *Student Teaching Seminar*. It is during this latter course that students are required to complete a minimum of 20 hours of site-specific clinical experiences finding out about the cooperating teacher's procedures, getting to know the school's personnel and policies, and working extensively with some of their future students. Pre student teachers write up their experiences and findings, and share these in a seminar which takes place on campus on a weekly interval. These activities smooth the way for a teacher candidate to begin the student teaching practicum. Both cooperating teachers and school administrators and staff, have repeatedly remarked to the University supervisor of the practicum how helpful these experiences are not only for the student teacher, but for school personnel as well.

Throughout the rest of this article, readers will find that each pre student teacher is required to conduct seven conferences with his or her cooperating teacher, and a similar number with key academic and support personnel. In addition, pre student teachers must also work with and get to know individual students with specific needs who will be enrolled in the courses to be taught. In cases dealing with interviews, lists of suggested questions are provided, the answers to which pre student teachers must write about in weekly reports, and also discuss in weekly seminars.

The clinical experiences presented here are of two types, required and supplemental. Twenty clinical experiences are required of all students enrolled in the required Physics 353 course. If conditions prevent one of the required experiences from

being carried out, students must select a replacement from among the supplemental clinical experiences. In addition, some student teachers will complete supplemental clinical experiences if they feel that they have had inadequate experiences in specific areas during the 100 clock hours required prior to the beginning of the student teaching semester. Surprisingly, with as busy as the pre student teachers tend to be, most will elect to complete many of the supplemental experiences to further their professional development.

These pre student teaching clinical experiences are presented here as an "offering" to teacher education faculty and cooperating teachers everywhere, as one possible way to help improve the quality of physics teacher preparation. Interested teacher educators are encouraged to employ these activities.

## CONFERENCES WITH COOPERATING TEACHER

### Clinical Experience # 1 - Expectations

Student teachers, cooperating teachers, and university supervisors will all have certain expectations for the student teaching practicum. The best time to become aware of these expectations is prior to beginning student teaching. Arrange a conference with you cooperating teacher, and with your university supervisor if you feel it necessary, to discuss expectations. Prepare thoroughly for such conferences, and be certain that you come with a list of questions and/or concerns. This is a good time to find out answers to the following and similar questions:

- \* What sort of expectations do you have for my student teaching experience?
- \* What sort of things have you learned for working with clinical students and/or student teachers that I should know about?
- \* How might I make the student teaching experience the most useful?
- \* How will you assess my day-to-day teaching performance?

- \* How do you want me to work with you on a day-to-day basis?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience # 2 - School Policies**

Schools are bastions of policy. That is, there will almost always be a policy of one form or another to cover just about every situation. You can rest assured that school personnel have seen just about every sort of situation possible. Conduct a conference with your cooperating teacher to determine what these policies are. Prepare thoroughly for such conferences, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* Is there a school policy manual for teachers? May I have a copy?
- \* Is there a school policy manual for students? May I have a copy?
- \* Who sets the various policies at school?
- \* What are the school policies with regard to safety?
- \* What are the school policies with regard to security?
- \* If I have a question about a policy, who do I ask?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience # 3 - Classroom Procedures / Policies**

Teachers, too, are bound to have policies that extend to just their classroom. These policies can vary from teacher to teacher, but many will be the same. Such policies will include management of what students should be doing at the beginning of class and will extend all the way to class dismissal. Conduct a conference with your cooperating teacher to determine what these policies are. Prepare thoroughly for such conferences, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* What are your classroom policies with regard to bringing textbooks to class?
- \* What are your classroom procedures / policies with respect to classroom discipline?
- \* What are your classroom procedures / policies with respect to grading, testing, homework...?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience # 4 - Parental Contact**

Parental contact will be required of you on an ordinary and usual basis. This generally takes the form of regularly scheduled parent-teacher meetings. In addition to these contact, special contact may be necessary for any number of reasons — some

good and some not so good. Conduct a conference with your cooperating teacher to determine what the policies are relating to extraordinary parental contact. Prepare thoroughly for such conferences, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* What are the policies and procedures for initiating extraordinary parental contact?
- \* What circumstances or conditions warrant extraordinary parental contact?
- \* What procedures should I follow when dealing with parents over an unfortunate circumstance?
- \* Are the conditions under which the school administration should initiate contact in lieu of me doing the same?
- \* What general guidance can you provide me for working directly with parents?
- \* How might I engage parents to work with me in a positive fashion?
- \* Are there parents out there that can be engaged as special resources for my teaching?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience #5 - Instructional Planning**

Student teachers sometimes find instructional planning a mystery. Student teacher need to speak with their cooperating teachers to find out answers to the following questions:

- \* What should be taught?
- \* When should it be taught?
- \* What is the sequence?
- \* Is there a pre-planned curriculum that is supposed to be followed?
- \* Does that curriculum fit in with the inquiry-oriented approach, or is it based on expository teaching?
- \* What use is made of the National Science Education Standards and of the Illinois Learning Standards in planning?
- \* How does state-mandated testing affect this course?
- \* What is emphasized here, depth or breadth of coverage?
- \* What modifications must be made for student abilities?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience #6 - Student Assessment**

Student teachers should become familiar with syllabi and student assessment strategies as they relate to grade determination in particular. Interview your cooperating teacher, and obtain answers to the following and similar questions:

- \* How many assessments?
- \* What is assessed?
- \* What type of alternative assessments are used?

- \* How do you maintain grades?
- \* Do you use rubrics?
- \* When is testing done?
- \* What are your makeup policies?
- \* Are your policies now my policies?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience #7 - Teacher as Ethical and Reflective Practitioner**

Teachers improve their practice over the course of years by reflecting on their work. Student teachers should become familiar with this form of learning experience by interviewing the cooperating teacher. In addition, student teachers need to understand the nature of professional ethics as they relate to teaching. Hold an interview with your cooperating teacher to obtain answers to the following and similar questions:

#### Ethical practitioner questions:

- \* Does this school district have a professional code of conduct?
- \* If so, may I have a copy of it?
- \* What can you tell me about ethical practice?
- \* What is the most common form of unethical teacher practice as you see it?
- \* Can you give me any pointers about being an ethical teacher?
- \* How does school policy figure into ethical practice?
- \* Where do you go to find answers to questions about ethical conduct as a teacher?

#### Reflective practitioner questions:

- \* How have you improved your professional practice over the years?
- \* What role does reflection play in your professional development?
- \* What sort of changes have you made as a result of reflection upon your professional practice?
- \* What has reflection taught you that your teacher preparation did not tell you about?
- \* What role does reflective practice play in your ongoing teacher certification and professional development plan?
- \* How do professional relationships play into your ongoing improvement as a teacher?
- \* What personnel or professional agencies figure into your professional development?

Prepare a short, written summary of you findings. Use a question-and-answer format to document your experiences.

### **Clinical Experience #8 - Material Resources**

Student teachers need to know what sort of demonstration and laboratory equipment is available prior to beginning student teaching, especially for those units the teacher candidate will be

expected to teach. Therefore, it would behoove the student teacher to check with the teacher about such material resources, and request tour of all pertinent storage facilities. Following this tour, student teachers should create a list of the topics that they will be expected to teach over the next ten weeks, and then conduct an inventory to determine what material resources are available for teaching these units. Do so for both

- \* demonstration materials by unit topic
- \* laboratory material by unit topic

Prepare a short, written summary of you findings. There is no need to be exhaustive; a list of major items will suffice. Use a question-and-answer format to document your experiences.

### **Clinical Experience Supplement A - Time Management / Organization**

Student teachers are almost always bowled over by the great demands of time associated with the practicum. Sometimes this results from the overwhelming amount of work required on an almost daily basis. Speak with your cooperating teacher about how to improve performance and efficiency in dealing effectively with those things that appear to consume your day. Ask for advice about avoiding the problems of over engagement in nonacademic matters. Prepare thoroughly for such conferences, and be certain that you come with a list of questions and/or concerns. Prepare a short, written summary of you findings. Use a question and answer format to document your experiences.

### **CONFERENCES WITH ADMINISTRATORS, CONFERRAL AND REFERRAL PERSONNEL**

#### **Clinical Experience # 9 - Assistant Principal**

The assistant principal or dean of students in a high school will frequently be the school disciplinarian. That is, at least one person will be in charge ultimately of dealing with unruly students, with the management of detention, contacting parents for disciplinary matters, and so on. In this activity you will contact and hold a short discussion with the person (assistant principle, dean of students, or whoever) who works as the school disciplinarian. Check with your cooperating teacher to find out who this person is, and to arrange for a short meeting with this person to discuss school policy and procedures with regard to disciplinary matters. Prepare thoroughly for the conference, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* What is the school policy with regard to sending students to the office?
- \* What sort of procedures must be followed with unruly students, from the smallest of transgressions to those constituting criminal conduct?
- \* What advice can you give me for dealing with disruptive students?

- \* What conditions warrant referral of a student to your office?
- \* What other “services” does your office provide?

Prepare a short, written summary of you findings. Use a question and answer format to document your experiences.

### **Clinical Experience # 10 - School Nurse**

School nurses are in place for a variety of reasons, not the least of which involves dealing with emergency matters of health. Still, it will be a rare event that school nurses will have to deal with emergency events. So often school nurses deal with other important matters such as the general health of students, and the dispensing of drugs and medications to students. Check with your cooperating teacher to find out who this person is, and to arrange for a short meeting with this person to discuss school policy and procedures with regard to health matters. Prepare thoroughly for the conference, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* What are your role and responsibility in the school setting?
- \* What should I know about the management of health matters in the classroom?
- \* What are school policies in relation to the transmission of diseases such as mono, HIV-AIDS, hepatitis, etc.?
- \* What is the school policy with regard to students self-medicating?
- \* How do I deal the emergency health problems?
- \* What constitutes an emergency health problem?

Prepare a short, written summary of you findings. Use a question and answer format to document your experiences.

### **Clinical Experience # 11 - Guidance Counselor**

Nearly every high school has one or more guidance counselors. Guidance counselors generally have a variety of tasks, but they often include providing assistance to students making decisions about careers, about arrangement of class schedules, management of study habits, and dealing effectively with learning difficulties. Sometimes guidance counselors even serve as school disciplinarians. Check with your cooperating teacher to find out who this person is, and to arrange for a short meeting with this person to discuss school policy and procedures with regard to guidance matters. Prepare thoroughly for the conference, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* Please describe the range of your roles and responsibilities as a guidance counselor.
- \* How might I take advantages of your services to help my students?
- \* What sort of resources are available through your office?
- \* When should I refer a student to your for assistance?

Prepare a short, written summary of you findings. Use a question and answer format to document your experiences.

### **Clinical Experience # 12 - Special Education Personnel**

Sometimes students appearing in a classroom will have special educational needs. This is not to imply that these people are unintelligent or have a mental disability. Special education needs can also result from students with disabilities or handicaps. With the earmarking of federal funds, each school system and each teacher must deal effectively with special student needs when the arise. Schools will have people whose mandate is to provide for special education needs. Check with your cooperating teacher to find out who this person is, and to arrange for a short meeting with this person to discuss school policy and procedures with regard to special education matters. Prepare thoroughly for the conference, and be certain that you come with a list of questions and/or concerns. This would be a good time to find out answers to the following and similar questions:

- \* What sort of services do you provide?
- \* Under what conditions should students be referred to you?
- \* Does your office provide assistance directly to teachers and student teachers?
- \* What can you tell me about individualized instructional plans for students in my classes?
- \* What are my responsibilities mandated by law with respect to student with special educational needs?

Prepare a short, written summary of you findings. Use a question and answer format to document your experiences.

### **Clinical Experience #13 - Instructional Technology Coordinator**

Almost every high school will have a person in charge of instructional technology. Instructional technology can include anything from slide projectors and videotape units to school-wide computer networks that support Internet usage and grade and attendance record keeping. This person probably is today a computer specialist with some responsibilities in the area of working with computers and audio/visual resources. It’s good to get to know this person to find out about the various resources that you will be able to access during your student teaching practicum. With the assistance of your cooperating teacher, set up a meeting with the school’s technology coordinator and obtain answers to the following and similar sorts of questions:

- \* What are your job responsibilities, and how do they relate to my teaching?
- \* What sort of instructional media do you have available for me to use?
- \* What need I do to obtain access to your instructional technology offerings?
- \* Is there anything in particular that I need to know in relation to the use of instructional technology at this school?
- \* What sort of assistance and/or training do you provide teachers in need?
- \* Who do I turn to if you are not available when I need you?

Prepare a short, written summary of you findings. Use a question and answer format to document your experiences.

#### **Clinical Experience #14 - Science Department Chairperson**

Schools are administrative units with a variety of support structures. Under the school administration there is a layer of bureaucracy known as department heads or chairpersons. These are usually senior faculty with years of experience within the school system. They have a variety of responsibilities and duties. As a novice teacher, you undoubtedly will report directly to your science department chairperson. It is important to know the role and responsibilities of these individuals in your school district. With the assistance of your cooperating teacher, arrange a meeting with you science department head. Obtain answers to the following and similar sorts of questions:

- \* What are your job responsibilities and duties included among such things as scheduling, preparing teaching assignments, and allocating budgets?
- \* How would I as a regular inservice teacher be responsible to you in this school district? As a student teacher?
- \* What sort of duties do teachers have to their department?
- \* Where do you figure into the chain of command in this school?
- \* Do we have regular department meetings? When and where?

Prepare a short, written summary of your findings. Use a question-and-answer format to document your experience.

#### **Clinical Experience #15 - Attendance Personnel**

Attendance personnel in schools have a very important job. School-wide budgets are frequently based upon the number of students in school over the course of the year. It is therefore critical that such personnel maintain accurate and complete records. With the assistance of your cooperating teacher, arrange for an interview with the school attendance officer. Obtain answers to the following and similar sorts of questions:

- \* What is your role and responsibility in this school?
- \* How do you manage your job?
- \* What are my duties in this area as a teacher?
- \* How do you and the teachers handle absences, tardies, and trancies?
- \* How can I as a teacher make your job easier?

Prepare a short, written summary of your findings. Use a question-and-answer format to document your experience.

#### **Clinical Experience Supplement B - Superintendent, School Board Member, or Union President**

There are a number of key players in the school and district offices besides those you have already spoken to about various matters. As an alternative pre-STT clinical experience (or even as an addition), you might want to meet with the school

superintendent (hiring practices for instance), a school board member (authority and accountability matters), or the president of the local teachers' union (representational and defensive matters). Check with your cooperating teacher to find out who these person are, and to arrange for a short meeting with one or more persons. Prepare thoroughly for the conference, and be certain that you come with a list of questions and/or concerns.

#### **Clinical Experience Supplement C - Attend a School Board Meeting**

School boards oversee the school system and, therefore, it would behoove the candidate teacher to attend one such session. Attend one such session and report on you the events, and provide a bit of additional commentary about your reactions.

#### **Clinical Experience Supplement D - Get to Know Your Community**

Many student teachers don't know the community in which they will teach. Therefore, it would benefit student teachers to spend a bit of time observing the members of the community, and reflecting on those observations. As a starter, sit down in a local restaurant and watch the patrons. Do the same in other locations such as community stores, and the library. Record your observations and reflections. Answer such questions as, "What is the nature of this community? What impact has education had on this community's members? Is education highly valued in this community?"

### **WORKING WITH STUDENTS**

#### **Clinical Experience # 16 - Individual or Small Group Tutoring Session**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to conduct an individual or small group tutoring session. Prepare a short paragraph describing your experience.

#### **Clinical Experience # 17 - Student with Special Needs**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to work directly with a student with special needs related to a mental or physical disability or handicap. Prepare a short paragraph describing your experience.

#### **Clinical Experience # 18 - Assisting Students with Laboratory Experiences**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to assist students with a laboratory experience. Prepare a short paragraph describing your experience.

**Clinical Experience # 19 - Test or Quiz Administration and Grading**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to assist students with a laboratory experience. Prepare a short paragraph describing your experience.

**Clinical Experience # 20 - Managing a Class Discussion**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to manage a class discussion. Prepare a short paragraph describing your experience.

**Clinical Experience Supplemental E - Conduct a Pre-Lab Orientation or Post-Lab Debriefing**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to conduct a pre-lab orientation or post-lab debriefing. Prepare a short paragraph describing your experience.

**Clinical Experience Supplement F - Set Up or Take Down a Lab Activity**

As a transitional activity leading up to student teaching, arrange with your cooperating teacher the opportunity to set up or take down a laboratory activity. Prepare a short paragraph describing your experience.

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In addition to serving as a course to provide transitional clinical experiences, the Physics 312 seminar continues along side student teaching. Student teachers come together approximately once every three weeks to share experiences, gather additional teaching sources from the University's Physics Teaching Resource Center, and to hold prolonged discussions with the University student teaching supervisor.

These meetings also allow the supervisor to work with students on their professional teaching portfolios and weekly reflections and reports that are also a part of the course. In their portfolios students present evidence that they are able to teach science in compliance with National Science Teacher Association directives, the Illinois Professional Teaching Standards, and the University teacher education program's conceptual framework *Realizing the Democratic Ideal*. Information about these other aspects of the course may be viewed online through the course's web site at <http://www.phy.ilstu.edu/pte.html>.

The logo consists of the letters J, P, T, E, and O in a large, bold, serif font. The letters are slightly slanted to the right and have a decorative, shadowed appearance.