Disclaimer: The article below is taken from Allan Feldman's website http://people.umass.edu/afeldman/. I had adjusted the formatting and added the italics to emphasize the significance of the discussion. This particular paper is a good introductory paper. I was honored to be at the Orono AAPT conference when this paper was presented

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Teachers as Researchers: 'Getting Smarter' About Physics Teaching Through Systematic Inquiry

http://www-unix.oit.umass.edu/~afeldman/Getting.smart.html

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Teachers as researchers

Research and teaching are activities that have gone hand-in-hand since the first time a person learned something new and shared that knowledge with others. In this sense, teachers have always done research, and researchers have always taught: the generation of knowledge and the sharing of it with others has long been tied together. It has only been recently that the two endeavors have been divorced so completely from one another that it is possible to talk of a group of individuals whose principal endeavor is to inculcate in novices the accumulated knowledge of the disciplines, and another group for whom the generation of that knowledge is of prime importance. There are of course many who can, and do, combine these two undertakings and are recognized for what they have done to further the field and for their ability to encourage and aid others in the learning of that knowledge.

For the most part the people who are researchers and teachers are researchers first, and teachers second. They are found in universities and colleges although there is a scattering of school teachers who are able to do original research on the side. There is the physicist who is known both for his research and the ability to excite a lecture hall full of freshmen as they are introduced to the wonders of physics. There is the school teacher who has had the opportunity to do research as part of an undergraduate or graduate program, or in programs like ISME that have provided classroom teachers with the opportunity to engage in scientific research activities during the summer. And there are a hand full of teachers, such as Jim Minstrell, who have been able to do meaningful and important research, in his case on the learning of physics, while employed as full time secondary school teachers.

In this paper I would like to narrow the discussion to that of school teachers of physics who are engaged in research. This still leaves a wide variety of activities that these teachers can be engaged in. For example, many teachers, as part of advanced degree programs are engaged in research for their theses. For some, this research is in science and for others it might be in education. The teacher research that I am dealing with in this paper is primarily concerned with teachers' own practice. What I and others mean by teacher research is

research done by teachers on their own practice -- an inquiry into their teaching in their classrooms. Because this research is focused on the work of the researcher, it is developmental in nature and has two main purposes. The more immediate one is an improvement in practice. When teachers engage in research on their practice, their immediate goal is to get better at what they do. The second purpose is to gain a better understanding of the educational situations in which they are immersed. This better understanding is in some ways equivalent to the generation of knowledge. But while knowledge is thought of as generalizable in space and time, and codifiable in propositions, the understanding that a teacher develops of his or her educational situation is located spatially and temporally, and can be shared with others as stories or other forms of narrative.

Research

Before I describe what I mean by this self-developmental teacher-research in more detail, review its benefits for the teaching profession, and reevaluate it in light of what I have found in my own research, I will digress a bit in order to begin to answer some fundamental questions:

> "What do we mean by research?"
>
> "What are the purposes of research?"
>
> "What are the processes that teachers go through when they do research?"

The first question is the more difficult of the three because it is a term that can suggest certain stereotypes in people's minds. "Research" can suggest men in white lab coats with wild hair, or to those more familiar with scientific research, controlled experiments and quantitative measurement. This latter conception of research was apparent in a discussion a colleague and I had with new science teachers about research in science education. We asked them to search through journals that we identifiable as "research journals" for articles that caught their interest. In class, they each presented a summary of their article, told why they had selected it, and then told why they had rejected others. In assessing the articles that they read, we heard the following comments:

> “I found them a lot less rigorously done than the articles in plant pathology. [There was] not much replication. ... Some [of the articles] were very anecdotal. ... It's hard to do a rigorous experiment with kids.”
>
> “[The articles] seemed more opinion, like an editorial, not like research. ... [They] did not cite methods or analyses ... [they] did not substantiate a base.”
>
> “[The research was] not well conducted ... [it] did not have control groups. [The] research itself was not rigorous.”
>
> “[The researcher] used a small sample, 60 students...”
>
> “It wasn't research because they only looked at one classroom. They should have looked at more classrooms.”

> "Two things that you're supposed to look at when you test a hypothesis [are] duplicability and reliability. Just by looking at two classes I don't think that you can prove the two."

These comments suggest that these masters level students view research as quantitative, consisting of either very large surveys or carefully controlled, replicable experiments, and that the single purpose of research is hypothesis testing. I have found similar conceptions of research when working with experienced science teachers.

Since the ordinary conception or research, even among people educated in the sciences, is limited, it might be more useful to try to answer the second question and then return to the first. *When a person researches, he or she reasons*. Aristotle, in his major ethical treatise, the Nicomachean Ethics, identified several categories of reasoning. They include what we would call scientific or theoretical reasoning (*epistemé*), technical reasoning, that is applied science or art (*techné*), and practical reasoning (*phronesis*). *Scientific reasoning is concerned with how one knows what or that, technical reasoning is concerned with knowing how, and practical reasoning is concerned with knowing what to do. In others words, a physics teacher is reasoning scientifically when wrestling with the question, "What are the effects of Aristotelian prior conceptions on my students' construction of their understandings of Newtonian mechanics?" The teacher uses technical reasoning to determine teaching methods that help students to construct their new conceptions of Newton's Laws. And the teacher is using practical reasoning when deliberating about how best to implement those methods to suit the abilities, needs, and interests of these students in this physics class in this school at his time*.

Each of these varieties of reasoning is associated with a purpose, or goal, of research. Following Aristotle's categorization, *we can talk about scientific, technical, and practical research, where the goal of scientific research is to generate new knowledge, the goal of technical or applied research is to figure out how to do something, and the purpose of practical research is to make defensible decisions about what actions to take*.

Returning to the first question, *research could then be defined as the process that people use to reach one or several of these goals*. This operational definition of research might seem lacking. That is, it is not enough to define research by stating what the goals or purpose of research are. There are some other possibilities. One is to go to a dictionary. According to The Random House Dictionary of the English Language (1987), *research is "diligent and systematic inquiry or investigation into a subject in order to discover or revise facts, theories, applications, etc."* This dictionary definition is similar to the one that is evoked in people's minds when they hear the word *"research."* It can be formalized, using the philosopher's definition of knowledge, as *a systematic process which generates knowledge, where knowledge is warranted true belief*. A difficulty with this definition is that it truncates the possibilities for research -- research is confined to a search for The Truth, and the other purposes for researching are not allowed. The Random House definition is a bit wider, allowing rese arch in order to discover applications of facts and theories, but relegates all other purposes to "etc."

A more inclusive definition arises from the work of the late British educator, Lawrence Stenhouse. *He defined research as systematic, critical inquiry made public (Stenhouse, 1981). Therefore, according to Stenhouse, research is a process of inquiry that is systematic, critical, and public. Research is systematic when the person doing the research, in our case a teacher, has developed some sort of plan that moves the inquiry away from being haphazard or random*. It is important for it to be systematic so that there is some way that the teacher can convince others that the knowledge generated is true, or that the teaching technique works, or that the action taken is defensible.

Research is critical when the researcher challenges assumptions and findings of not only others but also her or his own. This critique can be similar to what Karl Popper has suggested -- a researcher attempts to confirm his or her conclusions by trying to disprove them (Popper, 1972). This Popperian notion of scientific proof is integral to what we mean by critical. But to be critical also means to ask the questions such as Arnold Arons question, "How do I know?" and "Are there any other reasons to believe that this is true, or that this is the best way to do, or that this is the most defensible choice?"

To make research -- its results and its processes -- public, is to make it open to the critique of others. This is an important part of what occurs in scientific research communities. Scientists and other professional researchers publish their findings and present papers at meetings of research societies so that their peers can respond to both the method and the veracity of their work. It is through this public display and scrutiny that other researchers learn about the results of the research and any new methodology that was developed as a result of it. And it is through public criticism that the truth of these claims is assessed.

Public communication of one's work is an integral part of the professional research communities. It is lacking in most teachers experiences. *The world of teaching is insular -- teachers rarely have their work viewed or commented upon by peers. They are in public view, but their public consists of children or adolescents who often are critical of their teachers' teaching but are not in a position to provide critical feedback.*

Inquiry

Research is a process of inquiry. But what does this mean? A revisit to the dictionary provides some help: *Inquiry is "a seeking or request for truth, information, or knowledge* (Random House, 1987)." *But the dictionary leaves out inquiry in order to find out how to do, or in which way to act*. However, what is more important to teachers than a statement of what is sought through inquiry would be some way to describe this process. A few words of caution here: Any process of inquiry is a heuristic. It is a general overview of a process that is free to vary and flow, much like the way the course of water in a river is modified by the terrain. In laying out processes in detail, there is the tendency to restrict the process to a single path, a channeling of the raging river to a concrete aqueduct. In this way, a heuristic is collapsed to an algorithm, a step-by-step detailing of a method, and the inquiry process is stymied.

And so, in order to leave open the fluidity of the heuristic, we can look at this process of inquiry through the words of a number of seekers. The first is one who is known not so much as a researcher but as an environmental activist. John Muir, in addition to founding the Sierra Club and helping to establish the National Park system, was an accomplished naturalist. As he voyaged through the high Sierras of California he identified new species and attempted to unravel the mysteries of glaciation. In the forward to a reprint of his guidebook to what is now Yosemite National Park, Michael Cohen quotes Muir as giving this description of his inquiry process:

I drifted about from rock to rock, from stream to stream, from grove to grove, Where night found me, there I camped. When I discovered a new plant, I sat down beside it, for a minute or a day, to make its acquaintance and hear what it had to tell. When I came to moraines, or ice-scratches upon the rocks, I traced them back, learning what I could of the glaciers that had made them (Muir, 1986).

To Muir, inquiry was a serendipitous process, but one of careful observation. A certain path might lead him to a particular plant or specific signs of glaciation in what might seem to be a random manner, but his careful eye helped him to choose which path would help him find the evidence that would lead him to new discoveries or new conclusions. His wandering were far from random they were a process made systematic by his critical eye and his prior knowledge. Muir's research included a feedback mechanism of sorts. The discovery of a new species of plant connected to that which he already knew. The ecological niche in which it grew told of seasonal variations in weather, of the age of rocks, and of other species of plants and animals. This information would then lead him to walk other paths to seek out confirming or disconfirming evidence.

For those who find Muir's perambulatory method of research too unsystematic, Popper's codification of the research method might be more useful. In his book Objective Knowledge: An evolutionary approach (1972), Popper claimed that the research process has the following form:

P1---> TT ---> EE ---> P2

where P1 is the initial problem, TT is a tentative solution or tentative theory, EE is the subjection of the theory or solution to the process of error elimination, and P2 is either the original problem restated in light of the research or a new problem which has arisen through the research process. What he outlined is a process in which a person begins by first taking note of a certain problem.

Although this formulation suggests that this is an outline of a scientific research process, there is no need to restrict the problem to that of discovering or generating new knowledge. It could be a technical problem or one of choosing defensible action. In any case, once the problem is identified, some sort of tentative solution is proposed. It could be a propositional statement of some theory. For example, if lessons are preceded by an advanced organizer, student learning will improve. Or it could be a new method of assessing students: In order to have a more authentic assessment of my students' progress through their course of study, I will evaluate them using portfolios. Or, it could be a decision about how best to react to a student whose behavior is disrupting the class. In all cases the next step is to test the tentative solution. This could be done through a controlled experiment, or through surveys in order to test hypotheses, but it can also be done by comparing the results of using a new method to the projected goal, i.e., whether assessment by portfolio is more "authentic," or by seeing how well the results of the action taken match the desired outcome -- Does speaking to the student privately after class change her behavior?

At this point, the researcher reassesses the situation. Has the problem been "solved?" Or has the result of this inquiry been to better define the original problem, or to suggest that there is another problem that needs to be dealt with? Again, we see a feedback mechanism. What is learned as the researcher gets "smarter" about his or her inquiry is fed back into the research cycle as a way to use the critical aspects of the error elimination step.

John Dewey (1933) modeled the research process in a manner similar to Popper's:

Problem ---> Supposition or Plan ---> Observation ---> Data ---> Idea --->

Observation ---> Test by observation ---> Facts ---> New Idea --->

Test by Action

Dewey's model of research fleshes out the error elimination process. He saw it as a complex series of steps of observations, collection of data, generating ideas from that data, testing those ideas against the observations, coming up with a new idea, and then testing it by action. In his model, Dewey distinguished between testing by observation and by action, the distinction that Albert Einstein made when he spoke and wrote of thought experiments. It is not always necessary to do the experiment, or produce the technology or take the action to discover whether or not the proposition is true, or the gizmo works, or the action is the most defensible. Observation and reflection can lead to new ideas which are then tested by action.

Although it is not explicitly spelled out above, the cyclical nature of the inquiry process and the implicit feedback mechanism are included in Dewey's model. Clearly it exists within one run through the process. The feedback and modification of problem statements and ideas run through this conception of research. But it is apparent from Dewey's work that in the process of testing by action, observations are made, reflecting occurs, and a from which a new problem or understanding of the original problem arises.

What each of these models of research or inquiry seem to lack is a first step. *How do you go about finding what is the problem or dilemma that you want to investigate?* The authors of these models might leave them out because the answer, once thought about, is so obvious -- the problems and dilemmas are all around the researcher. They arise from the interest in finding out more about the world, trying to develop some new technology, or the need to make a decision and act on it. *Kurt Lewin formalized this by inventing what he called action research* (Elliott, 1991). From a careful look at his model we can see what makes action research special -- Lewin identifies the source of particular research projects within the world of the researcher (Elliott, 1991).

Identify a good idea ---> Reconnaissance --->

General Planning ---> Develop the 1st Action Step --->

Implement the 1st Action Step ---> Evaluate --->

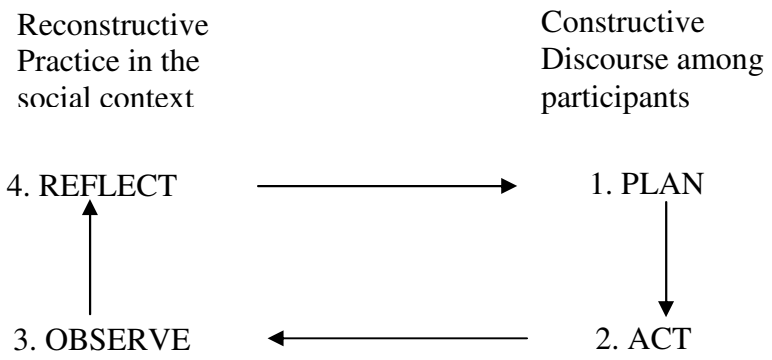
Revise the General Plan ---> Develop the 2nd Action Step ---> Continue through the Cycle

Action researchers inquire into their own practice. They are trying to come to a better understanding of their situations, which in the case of teacher action research are educational situations, as they develop better ways to teach, and choose the most defensible ways to act in doing so.

Action Research

It is action research that has served as a model for my interactions with teachers as I have encouraged them to research their own teaching. Although the idea seems to have originated with Lewin, its contemporary incarnation has come out of the work of Stenhouse and his colleagues, notably John Elliott (1991), in Britain. My understanding of what action research is has been influenced by Elliott's work and by Wilfred Carr and Stephen Kemmis (1985). *In their model, the research process is shown clearly to be cyclical and to have feedback built in. I will illustrate the four stages of their action research cycle, planning, acting, observing, and reflecting* by taking a look at the process used by students in the Stanford Teacher Education Program (STEP) during the 1990-91 academic year. Their initial assignment was to identify some sort of educational problem that was of interest to them,

and to then refine the statement of their problem through reflection, consultation with staff members, and in collaborative discussions with other student teachers and interns.



During the fall quarter of 1990, work on their projects focused on the planning for the research that the STEP student teachers and interns were engaged in during the winter quarter. The planning, which included identifying pedagogical or curricular problems and devising ways to act in order to solve those problems, was part of Carr and Kemmis's constructive phase of action research. For physics teachers, an action might be a new way of performing an experiment or doing a demonstration. For English teachers, it might be the introduction of regular journal keeping. Foreign language teachers might begin to teach more in the new language. The action could be a new seating arrangement, the introduction of a group work activity, or any of numerous possible innovations.

When the research entered the reconstructive phase, the STEP student teachers and interns observed the results of their actions, reflected on the actions individually and in consultation with his or her collaborators, who offered critical advice. New action plans were formulated which took into account the successes and failures of the original plan and its implementation.

Although this method of action research might appear to be circular, the classroom situation had changed and the knowledge of the STEP student teacher or intern had grown when he or she returned to the first stage. It is important to note that in a sense there is no end to this cycle because there are no final answers to the problems of improving practice or to coming to a better understanding of the complex nature of teaching. But as a result of this collaborative action research, the teaching of the STEP student teachers and interns had improved, other STEP student teachers and interns have learned from the successes and failures of their colleagues, and all have gained a better understanding of teaching through the shared discussion of the actions and ideas that arose in the research process.

As a part of a teacher education program, this exercise in action research had particular benefits. First there were the goals of the developmental research itself -- the student teachers and interns improved their teaching and came to a better understanding of the teaching enterprise. While doing so they learned to be self-critical, critical of their colleagues work, and critical of the "givens" of education. They also had experience working closely with others in their program, including STEP faculty, and teachers in the field in a way that many claim is missing from the teaching profession. In addition, they shared their new understandings with others at a conference held at the end of the year. Action research for these STEP student teachers and interns was a systematic and critical inquiry into their practice made public.

Reformulations and caveats

Since that time, I have been involved with two other groups of teachers engaged in action research. The first, the Physics Teachers Action Research Group (PTARG) has been a group of eight physics teachers and myself engaged in collaborative action research on the teaching of physics. The second group consists of 15 California science teachers who are part of the Scope, Sequence, and Coordination (SS&C) reform sponsored by the National Science Teachers Association (NSTA). These two groups differ significantly from the STEP teachers -- they are experienced teachers who are not enrolled in course work. My experience with these two groups has led me to reevaluate my understanding of teacher-research and to raise some caveats for those who would like to encourage teachers to become involved in it.

The California teachers were a part of what has become to be called the "100 Schools Project." More than 100 schools across the state have joined in this national effort to change the ways in which science taught. Of the nearly 1000 teachers involved, 15 from fourteen different schools have been engaged in action research in order to improve the implementation of the reform in their school or region. I have called what they have been involved in institutional action research because its primary purpose is to improve the implementation of the reform and not the development of the teachers as professionals (Feldman, 1992).

As I look back on the past year's activities with these teachers, I am aware of the successes of the project. Of the 20 teachers whose proposals we accepted last spring, 15 have completed their projects by writing reports of their activities. These reports are currently being edited and assembled into a book which will be available to the public in the fall of 1992. Some of the teachers have even solved the problems that they presented to us last year. But for most, this was a year of sorting through priorities and reflecting on what they have done and have not done.

It is apparent that the institutionalized nature of this action research and the fact that these teachers are practicing professional has impeded the research process. First, because the action research is imbedded in the larger project, the timetable of the 100 Schools Project determined the pace of the action research. It seems as if one academic year is not enough time for teachers to complete an action research project. In fact, it appears that the first year is a time for sorting through priorities, coming to an understanding of the research process, and of redefining the goal of the research. A second year is then needed to proceed with the project. This has also been the case with PTARG, and others who have facilitated action research groups have concurred.

A second impediment was also due to the institutionalized nature of this research. There was no distinction made between research for professional development (or implementation) and research for the purpose of program evaluation. To many of the teachers involved and to the directors of the 100 Schools Project, action research was seen as a way for teachers to evaluate the program at their schools. The teachers who attempted to do this found that it was a task well beyond the resources available to them. Interestingly enough, this problem was also due to my being a part of the research community and not that of policy makers. In my discussions with people about teacher research I have contrasted it with scientific research methods and not with evaluation research. But for those in the public schools, the primary purpose of research is for evaluation.

A third problem has been the geographic spread of the teachers involved. They were scattered through the state from near the Oregon border to as far south as San Diego. Because of this distance they have acted as individuals with my help. Again, it appears from

my work with other groups, particularly PTARG, and from the experience of other facilitators that one of the strengths of action research is that it builds a professional community. It is important that it be conceived as a collaborative process in which teachers share their expertise and comradeship with one another.

It is my work with the Physics Teachers Action Research Group which has resulted in the greatest challenges to my ideas of what action research is. PTARG began as an occasional meeting of physics teachers in the Stanford area to discuss the teaching of physics and to hear presentations from physicists on current research. During the spring of 1991 the opportunity arose for a group to be funded to do research as part of larger project under the direction of Lee Shulman, professor of education at Stanford University. The original goal of this research was to look at the ways in which metaphors, analogies, and other explanatory devices are used by teachers as they help students to construct their conceptual understandings.

During this past year, PTARG has met every three weeks to talk about what has happened and to plan new activities. Although all of the teachers were aware of the goals of the Shulman project when they agreed to be a part of the project, they each came to the first meeting with a personal project in mind. These individual projects proved to be of the most importance to the teachers and they resisted working on the Shulman problem. Many hours were spent discussing how to go about inquiring into the use of the explanatory devices, and several attempts were made to begin that inquiry. But each time there was resistance to doing so. Ultimately we rejected it and the teachers focused on their individual projects. In separate conversations with me they have told me that they would have agreed to follow through with the Shulman project if I had pressed them to do so. Because my interest was in how a group like this operates, I encouraged but did not push hard.

This raises two questions for me. The first is whether we can expect practicing teachers to engage in research that is not of primary concern to them. And the second is, when teachers are "held captive" in research projects by virtue of their being part of degree programs, does the research become just another rite of passage to get through and not be of concern again?

Working with physics teachers in action research has led to my thinking about the process itself in new ways. I had thought of action research as a modification of what happens in traditional research. Because of the subject under investigation, these methods for the most part would arise from ethnography and other forms of qualitative research including journal keeping, observations, and interviews. But in our discussions of methods in PTARG, the question was raised over and over again as to whether the analysis of data collected in these ways would tell a teacher any more than he or she knows through ordinary practice. Because this question was raised so often by one teacher, I have called this Erzberger's dilemma. Andria Erzberger would like to do more than the monitor and adjust that is reflection-in-action of practice (Schön, 1983). She wants to know more about her teaching so that when she changes it she has a basis from which to make those changes. She wants to base her decisions on what and how to teach on an understanding of what is happening with her students in her classroom. But this understanding seems always just out of her grasp. It is not there when all that she has to rely upon is her casual observations and her reflections on those observations. And when she attempts to be more systematic in her reflection -- to engage in systematic, self-critical inquiry -- it serves her no better. The data that she collects, or that others collect for her, are suspect because they do not meet the warrants for validity that she expects from her work in the physical sciences. She is caught in a void between the uncertainties of the observations made in practice and the demands that she puts on propositions before she will accept them as knowledge. That is her dilemma -- to be caught

between her need to know and the inadequacies of the methods available to her to warrant her observations sufficiently to meet her own standards.

It is this dilemma that has me moving away from urging teachers to use these research methods as they go about action research. It is not clear what more they get from them then they know from their expertise as teachers, and it requires more time than is available to them as teachers. In addition, it does not match the rhythm of teaching. Traditional research methods require that a "snapshot" be taken of some occurrence and that snapshot be analyzed over time. But teaching is not a series of stills. It is an activity that flows continuously from the start of one academic year to the next. It does not wait for the snapshots to be developed.

Conclusion

As a way to summarize this last section of this paper, I will list some suggestions that I would make to physics teachers who are interested in getting involved in action research, and to those who would like to aid them in that process.

- Give it time. It appears that it takes at least one year for the research process to get into gear. A second year would then be needed to begin to look critically and systematically at the teaching.
- It is a group activity. Teachers get the most out of it when it is done collaboratively with other teachers.
- It needs to be distinguished not only from scientific research but also from program evaluation. Program evaluation is a task that requires resources that are not available to teachers.
- The research questions should be generated by the teachers involved. The ownership of the questions can result in more ownership of the research.
- The methods of the sciences and social sciences are not appropriate for developmental teacher research. It requires resources that teachers do not have, does not satisfy their need to know, and does not match the rhythm of teaching. The methods of teacher-research must be imbedded in that what teachers already do.
- And finally, in order for teachers to engage in research, or any non-instructional professional activities, ways need to be found to teachers need provide them with release time.

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