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JPTEO

INSIDE THIS ISSUE

JPTEO: DOWN BUT NOT OUT

As I mentioned in the first issue of this publication, with the creation of any new publication there are bound to be difficult times, but especially at the outset. 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. This issue of JPTEO is labeled Vol. 2, No. 1. There was no June issue and the September issue has been considerably delayed due to a lack to suitable and timely submissions. Hopefully this is just one of the growing pains of a new publication. I have had several of our regular readers contact me recently asking when to expect the next issue; there appears to be a lively interest in the subject matter of this online journal. Our list of subscribers is now over 400, and the JPTEO Website receives several hundred "hits" on a monthly basis. If this publication should fail, it won't be for lack of readership.

Because of the current lack of suitable and timely submissions, JPTEO will be published on a semiannual basis until such time as the number of articles suitable for inclusion increases. As Editor-in-Chief of this publication, I'm now looking to publish JPTEO twice per year with issues in September and March. The March issue will be delayed, and probably won't make its appearance until May or June. Hence, there is still sufficient time for our readers to submit articles for consideration. I look forward to receiving contributions, and I already have one article that has been accepted for publication pending any changes required by our reviewers.

Please recall that JPTEO is not a "research only" type of publication. Articles that address any topic relevant to the teacher education or that directly address professional development processes are suitable for publication. Such articles might include description of "action research" by inservice teachers or teacher educators, summaries of teacher education activities that work, practical concerns with program development and accreditation, or essays on subject matter such as the goals and practices of inquiry or how to conduct authentic inquiry-oriented laboratory activities. If you have a passion about any of these topics, please consider writing for JPTEO. Should you have a question about the suitability of a topic, please contact me prior to writing your article.

In this issue of JPTEO you will find two articles dealing with the development of physics teacher education programs, moving from the traditional to the innovative. The first article by David Kagan and Chris Gafney deals with events now taking place at UC-Chico. The second article is a reflection on a set of circumstances that have allowed for the development of another innovative physics teacher education program at Illinois State University. Such articles will lay the foundation for future work in the area of high school physics teacher preparation. I again urge you to consider writing about your teacher education and professional development projects so that we all might learn from your experiences.

It is my hope as editor-in-chief of this publication that you will help to see that the *JPTEO* becomes a forum of lively exchange by submitting articles for consideration and publication. Detailed information about contributing to *JPTEO* can be found on the journal's website at *www.phy.ilstu.edu/jpteo.*

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JOURNAL OF PHYSICS TEACHER EDUCATION ONLINE

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EDITORS & REVIEWERS

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Building a physics degree for high school teachers

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Designing a program for prospective physics teachers involves many compromises. In this paper we report on the development of a bachelor's degree we have created in the Department of Physics at California State University, Chico. Our experience with our unique collection of choices and limitations may serve as a guide for others building similar programs.

Introduction

In 1998, Robert Ehrlich cited some very disturbing statistics[1]:

- The number of physics bachelor's degrees is at a 38 year low.
- The percentage of physics degrees to all degrees has declined by 75% since 1960.
- The percentage of physics degrees to all degrees has declined by 28% between 1986-96 while the number of students taking physics in high school has increased from 13.9 to 21.5%.
- The US Dept. of Labor projects only 500 openings per year for physicists and astronomers through 2005 while we produce two to three times that many each year.

According to the 2001 AIP Enrollment and Degrees Report, the situation has only gotten worse. The number of physics bachelor's degrees is now at a 40 year low[2]. There is certainly trouble brewing if small physics departments continue solely in their traditional (albeit highly effective) role of preparing students solely for graduate study in physics.

Ehrlich's statistics show a glimmer of hope and a bit of guidance. More students are taking physics in high school. Yet, only 33% of their teachers majored in physics or physics education while an additional 12% minored in physics or physics education[3]. This is an area where there is job growth for our profession and an opportunity for us to reverse the long downward trend in our enrollments. At the same time, we can take a stronger hand in developing a greater interest in our field among a broader population.

This paper describes the implementation of our "General Physics" degree designed specifically for students interested in becoming high school physics teachers. Since teacher certification processes vary from state to state, the first section contains some background information on the teacher credentialing process in California. The next section discusses some constraints in the design of the degree. The details of the degree program will then be presented and contrasted with our traditional degree. Next, we address the issues and concerns our faculty expressed as we developed and implemented General Physics. The last section contains a preliminary report of the effectiveness of the program.

The Credentialing Process in California

The State of California requires that students wishing to become high school teachers have "Subject Matter Competency" (SMC) before they enter a professional training program that is usually under the auspices of a university Department of Education. The professional training program at California State University Chico has several formats. The traditional program is one-year long and includes full-time study and student teaching. In the internship program graduates begin teaching directly after completing their SMC program, completing their coursework on nights, weekends and during the summer. In addition, there is a "flex" program for people currently employed outside the teaching profession. They complete their professional coursework at the same times as internship candidates.

SMC can be achieved one of three ways; completing a program of study in the subject that has been approved by the California Commission on Teacher Credentialing (CCTC), passing a prescribed exam on the subject matter, or through a waiver process. So, it became our goal to design a bachelor's degree in physics that would provide SMC in physics and be approved by the CCTC. In addition to the CCTC requirements, there are many other prerequisite courses demanded by our Department of Education for their professional training programs such as courses in adolescent health, linguistics, language and public speaking. There is also a requirement for 45 hours of volunteer time spent in a public school. Some, but not all of these requirements can be included as part of the general education requirements of the university.

Design Constraints on General Physics

CSU Chico is on the semester system. The university's general education requirements total 60 units[4]. Our traditional physics degree requires 70 additional units as shown in table 1. The central administration of the California State University system has mandated a maximum of 120 units for any degree. Our traditional degree can reach this limit because 4 units of math and 4 units of physics double count for general education. Our first constraint for General Physics was to avoid adding to the total number of units.

The second constraint was strictly financial. If any new courses are to be added to our offerings, they must be "cheap to teach." Physics departments always have financial issues in this regard because our total number of majors is small compared to other sciences. Adding a new collection of low-enrollment classes to the schedule was simply out of the question.

The third issue was the CCTC requirement for one year of biology and one year of geosciences for all secondary science teachers, which adds at least 14 units to our already full program.

Tugging at us also was the view of experts in the area of Physics Education Research (PER) that physics is far ahead of the other sciences in understanding how students learn. We felt that we should attempt to provide some experience where the students focused on educational methodologies in physics. As mentioned previously, the credential program requires 45 hours of volunteer time in a public school. This would be most beneficial to our students if this time were spent in a physics classroom. On the issue of PER, it might be noted that the insights of PER are beginning to change the way that many of our faculty members teach. Some of us use instruments such as the FCI and FMCE. Others use some of the techniques of peer instruction, active learning and JiTT. Our newest faculty member earned her PhD in PER. As a result, our students in both our traditional program and General Physics see a variety of pedagogical methods inspired by the results of PER.

Yet another issue stems from the fact that only 19% of high school physics teachers just teach physics[5]. The CCTC requires a total of 20 units in a second science to earn a supplementary authorization to teach the second science. In most cases, this would add 12 units to our program. Considering the fact that a substantial fraction of new teachers opt out of the profession, the need for a broad set of knowledge and skills was clear. As you will see below, in many ways General Physics can be thought of as an interdisciplinary physics degree.

Finally, we needed to be able to attract students. This could be a challenge considering the disparity in salary between most scientific and technical professionals and high school teachers. However, we had several assets. We have personal relationships with nearly all of the local high school physics teachers, our faculty value good teaching above other professional concerns and we have a large number of students in our service courses that haven't completely decided upon their career. We send emissaries out to local community colleges to make transfer students aware of our program. We shared our ideas at AAPT meetings and prominent author and physics educator Paul Hewitt established a scholarship for future high school physics teachers at our university.

The General Physics Degree

Our department has had a CCTC approved program for decades. Only one student had completed it in the previous two decades. This is because it was simply our traditional program with the additional requirements described above added on. The total number of units required was more than 160.

It was clear from the beginning that the only way to make an attractive and viable program was to design it train an effective future high school physics teacher not a future physics graduate student. We absolutely had to minimize the number of required units. It became evident rather quickly that these would have to come from upper division physics courses. We decided that the requirements for the traditional degree stated in table 1 as "core" were absolutely essential and we kept these same core courses for the General Physics Degree as shown in table 2.

The courses we would have to live without are listed as the "additional requirements" in table 1 and they are also listed in table 3 for comparison with the additional requirements for General Physics. While upper division courses in mechanics, electricity and magnetism, thermal physics and quantum mechanics are certainly our pride and joy, we came to the difficult conclusion that high school physics teachers could become excellent teachers without taking all of them. However, we did feel that potential high school teachers had to see a bit more than ten upper-division physics units in the core. We compromised at sixteen by requiring six units of upper division physics electives be part of the additional requirements.

Our Traditional Bachelor of Science In Physics

Course	Units
Lower-Division Core Requirements: 36 units	
General Chemistry	8 units
Analytic Geometry and Calculus	12 units
Elem Diff Equation/Vector Calc	4 units
Mechanics	4 units
Electricity and Magnetism	4 units
Heat/Wave Motion/Sound/Light	4 units
Upper Division Core Requirements: 10 units	
Modern Physics I	3 units
Modern Physics II	3 units
Advanced Laboratory	3 units
Physics Seminar	1 unit
Additional Requirements: 24 units	
Boundary Value/Partial Diff Eqs	3 units
Analytical Mechanics	6 units
Electricity and Magnetism	6 units
Thermal Physics	3 units
Quantum Mechanics	6 units

Table 1: The Traditional Physics Degree at CSU Chico. Note that the "additional requirements" are all upper division math and physics courses.

General Physics Bachelor of Science In Physics

Lower-Division Core Requirements: 36 units	
General Chemistry	8 units
Analytic Geometry and Calculus	12 units
Elem Diff Equation/Vector Calc	4 units
Mechanics	4 units
Electricity and Magnetism	4 units
Heat/Wave Motion/Sound/Light	4 units

Upper Division Core Requirements: 10 units	
Modern Physics I	3 units
Modern Physics II	3 units
Advanced Laboratory	3 units
Physics Seminar	1 unit

Additional Requirements: 35 units	
Upper Division Physics Electives	6 units
Earth Science/Geology	6 units
Biological Principles	8 units
Second Science Breadth Courses	12 units
Internship in Physics Teaching	3 units

Table 2: The General Physics Degree at CSU Chico.

The additional requirements also include the geology and biology courses to meet CCTC standards. The second science breadth courses have also been added to the additional requirements. These courses not only make the prospective teachers eligible for a supplemental authorization in the second science, but they provide an opportunity to apply their physics knowledge to another area of science. In fact, General Physics can be viewed as an interdisciplinary physics degree and students have used it in this manner.

Finally, the additional requirements include an internship course that meets the CCTC forty-five hour requirement. Our department maintains regular contact with the local high school physics teachers. Someone from our department visits every high school physics class in the local area at least once a year. This relationship with the local teachers allows us to ask them to take our students into their classrooms for the mandated forty-five hours. This, in turn, helps us maintain close contact with these teachers. You might note that this constitutes the addition of a low enrollment course. We were allowed to add this course because it is extremely cheap. In fact, no faculty member actually gets paid for it and the local physics teachers have our students in their classroom out of the goodness of their hearts.

Issues Raised by Faculty

While it may seem trivial, naming the degree brought to the surface many relevant issues. The most obvious name, Physics Education, typically refers to a course of study centrally focused on pedagogical issues. Due to the fact that CCTC requires this to be a degree in the content area of physics (not pedagogy) coupled with the inability to add additional courses in pedagogy, it certainly is not a degree in physics education. Besides, anything with the word "education" in the title could cause friction with the university's education department. Since our graduates would be entering their certification program, maintaining good relations with them would be valuable.

Some faculty felt that having the word "physics" in the degree title would be a misnomer because of the limited amount of upper division coursework. One faculty member was particularly concerned that a student might graduate with this degree, get into a physics graduate school and wind up embarrassing us. We settled on General Physics because some faculty felt that since the one-year algebra based course often has the same name, it would convey a "lesser" physics degree; "physics-lite" as one faculty member quipped. Others felt that General Physics expressed the interdisciplinary character of the degree.

We generally agreed on one aspect of the debate regarding rigor or lack thereof. There was certainly not sufficient rigor in physics alone. However, a degree composed of 28 units of physics, 16 units of math and 20 units in a second (lesser?) science certainly didn't lack rigor in an overall sense. In addition, this degree has more required units than the great majority of other degrees on campus, even our traditional physics degree. It is important to realize that physics departments' inability to compromise on physics rigor has contributed to the lack of physics majors pursuing careers in high school teaching.

Faculty pointed out that General Physics might reduce the numbers of students in our traditional program or force us to

ADDITIONAL REQUIREMENTS

Traditional Degree:	**24 units**	**General Physics:**	**35 units**
Boundary Value/Partial Diff Eqs	3 units	Upper Division Physics Electives	6 units
Analytical Mechanics	6 units	Earth Science/Geology	6 units
Electricity and Magnetism	6 units	Biological Principles	8 units
Thermal Physics	3 units	Second Science Breadth Courses	12 units
Quantum Mechanics	6 units	Internship in Physics Teaching	3 units

Table 3: A comparison of the additional requirements between the traditional degree and the General Physics degree.

reduce the rigor of our upper division core courses. In fact, the number of students in our traditional program has not changed. In addition, we agreed that core courses for both degrees must maintain high standards or we would not be providing the content component demanded by graduate programs or CCTC. In general we felt that our ability to add a teacher-training track was built upon the foundation of our strong traditional program. It is hard to imagine that the reverse could be accomplished. Building a strong traditional program out of a teacher-training department would be nearly impossible and definitely inconsistent with the intent of the CCTC.

A Preliminary Report

At this time we cannot report on the effectiveness of our program, as measured by the well-defined methods used in PER. Our program is new and our graduates are either just entering the teaching profession or have taught for a couple of years at most. However, we do believe our program is effective relative to the norm in California. Our program produces high school physics teachers who have had at least 28 units in calculus-based physics, and who have a genuine interest in and commitment to the discipline of physics, as evidenced by their choice of major. The typical California high school physics teacher has had at most 8 units of non-calculus physics, and would rather, most probably, teach their discipline of choice, as evidenced by their choice of major (Biology). Departments that are considering the creation of a major designed for future high school teachers may find useful the following narrative detailing the career paths of some of our graduates.

Including 1998-99 through the 2002-03 school year we have had 20 graduates. Seven of them in General Physics. The thirteen graduates that earned the traditional degree is about the normal number for us, so the seven General Physics graduates are additional majors that have added to our total number of graduates.

The first graduate in General Physics completed her degree in 1999. She entered the traditional professional teacher-training program and a year later applied for nine jobs. She had nine interviews! She chose a job for geographical reasons and as a result had a rather unpleasant first year of teaching. Like a large fraction of new teachers, she left the profession[6]. She immediately became a county health inspector, a job she still enjoys. There are several lessons we learned from this tale. First, the demand for high school physics teachers is very real. Second, we need to take a stronger hand in guiding the job selection of first year teachers. Finally, the value of the interdisciplinary nature of General Physics is vital for our graduates wherever they end up.

Of our seven General Physics graduates, three have taken advantage of the interdisciplinary features of the degree. There is the former teacher turned health inspector, one is working for an environmental firm in the private sector and the third headed off to graduate school in theology. One of our graduates decided to put her career on hold and raise children. Another completed the traditional professional teacher-training program this year and already has a teaching job at a high school about fifty miles away. The two that graduated most recently (June 2003) immediately got jobs in northern California and will complete their professional teacher-training as interns. The fact that these three got teaching jobs for the 2003-04 academic year in the current fiscal climate of the state of California is another testament to the demand for qualified high school physics teachers.

Clearly from these anecdotal reports, it is still too early to completely assess our program. In future years we hope to be able to provide a more thorough analysis of the success or failure of General Physics.

References

1 R. Ehrlich, "Historical Trends in Physics Bachelor Degree Output," TPT Sept. 1998.

2 P. Mulvey and S. Nicholson,""Enrollment and Degrees Report," AIP Report R-151.37 (August 2001).

3 M.Neuschatz and M. McFarling, "Maintaining Momentum: High School Physics for a New Millennium," AIP Report R-427 (August 1999).

4 Choosing classes that count in two categories can reduce this maximum number. The minimum number is approximately 48 units.

5 M.Neuschatz and M. McFarling, "Maintaining Momentum: High School Physics for a New Millennium," AIP Report R-427 (August 1999).

6 According to a recently reported statistic, more than half the new teachers in Los Angeles, California, give up their profession within 3 years. A 1996 study in North Carolina found that 17 percent of the state's teachers leave the profession after the first year in the classroom, 30 percent by the end of 3 years and 36 percent by 5 years. Nationally, 22 percent of all new teachers leave the profession in the first 3 years. These statistics are from A. DePaul, "The Survival Guide for New Teachers," U.S. Department of Education Pub. No. 065-000-01303-7 (May 2000), which can be found at http://www.ed.gov/pubs/survivalguide/message.html.

JPTEO

Change principles for departmentally-based physics teacher education programs

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The Physics Teacher Education program at Illinois State University has seen remarkable growth over the past ten years. This includes both the number of physics majors, and the number of physics methods courses designed specifically for teacher preparation. Program growth is attributed to a set of five conditions prevailing within the Department of Physics during this time. Teacher educators wishing to improve the size and quality of departmentalized programs at their own institutions might benefit from these same conditions. Nurturing these conditions at other institutions could assist with the process of significant, desirable, and lasting changes in their physics teacher education programs.

The Illinois Physics Department currently has in excess of 110 majors enrolled in four sequences: physics, physics teacher education, computer physics, and engineering physics. The overall undergraduate physics degree program is one of the largest such programs in the nation among departments offering only Bachelor degrees. Since 1994, the Physics Teacher Education (PTE) sequence has grown from a tiny fraction of all majors within the department to approximately 25% today. At that time there was one 4-semester-hour physics methods course, one 1-semester-hour lab course designed specifically for physics teacher candidates, and four PTE majors. Now, in the autumn of 2003, there are six

required undergraduate physics methods courses totaling 12 semester hours, and nearly 30 officially-declared physics teacher education majors. The dramatic rise in the number of PTE majors followed the creation of an improved undergraduate physics teacher preparation program, along with a very significant presence on the World Wide Web (see www.phy.ilstu.edu/pte.html). Program changes starting in 1994 with a new coordinator were predicated on the belief that if a model PTE program could be established and made visible using the resources of the World Wide Web, then students would come into the sequence in larger numbers. *This belief has been vindicated by a 600% growth in the number of PTE majors over the past decade, and the prospects for future growth are significant if the increasing number of program applicants is any indication.* Physics teaching minors are also enrolling in the program in increasing numbers, and some of these teacher candidates have chosen to become physics education majors. During the past two academic years, eight PTE majors and three PTE minors graduated from Illinois State University with physics teacher certification. This is significant in light of the fact that there are a total of 21 other institutions in Illinois offering PTE degrees with a historical combined graduation rate in the range of 5-8 majors per year. On a longer-term basis, ISU now graduates nearly 50% of all PTE majors in Illinois, and this percentage is growing.

The recent phenomenal changes in and growth of the PTE program at Illinois State University have resulted from an ideal set of conditions that have been nurtured within the ISU Physics Department over the past nine years. Reflection on the program revision process has led to the formulation of five "change principles" that might be used by other institutions attempting to enhance their own departmentalized PTE sequences, and increase their number of program majors. Program coordinators, departmental chairpersons, university faculty, administrative/professional staff, and project leaders involved with making significant changes in physics teacher preparation might do well to cultivate similar conditions within their own departments prior to attempting significant changes. These conditions should be nurtured if there is to be a reasonable hope of seeing maximum sustained progress in making program revisions and, ostensibly, increasing enrollments in physics teacher education programs. When properly nurtured, these conditions should help to make possible the sometime significant reforms required to create appealing programs of study for prospective students. Attempting to make significant changes without first taking into account the prevailing culture within a physics department can lead to significant resistance. Four of the identified change principles relate to the physics teacher education program coordinator, and a fifth is associated with departmental faculty. The change principles are enunciated as follows:

Change Principle 1: *If there is going to be significant, desirable, and lasting change in a departmentalized physics teacher education program, then an academic leader is needed who is personally committed to improving the teacher preparation process.*

A highly motivated, dedicated, and self-directed individual (or a team of such individuals) is needed to establish and manage a successful teacher education program. This includes the desire to give high priority to implementation of national, state, and local standards for teacher preparation, and dealing effectively with program accreditation processes. Teacher preparation accreditation at almost all levels today is based upon standards-derived outcomes and performance-based assessments. No longer is the focus on what courses and activities go into a teacher education program; the emphasis is on what students know and are able to do, and how these outcomes have been demonstrated and assessed using both formative and summative assessments. Because of this changing approach to teacher certification and program accreditation, and the difficulty of integrating these into one or two existing pedagogical courses, standards should come first. Several sets of national science standards have been developed that are research based and grounded on the experiences of tens of thousands of teachers among all major science disciplines[1,2,3]. Programs of study need to be aligned with and follow from these standards if the standards are to be comprehensively adopted and systematically implemented. This generally will require addition of new courses, clinical experiences, and performance assessments for teacher candidates. Ideally, standards will serve as the basis for planning and implementation of teacher education programs. The process of merely plugging selected standards into existing physics teacher education methods courses would best be avoided. Teacher educators should be willing to embrace the combined wisdom of the educational community as represented in science teaching and learning standards. Given the depth and breadth of the national, state, and professional standards, the day is gone when a single physics methods course can be said to successfully address the needs of teacher candidates. The improvement process must also include internal and external reviews and formative and summative assessments that are conducted periodically and objectively using clear and public criteria. Service learning projects, effective clinical experiences, and suitable student teaching experiences are also necessary. A faculty member, or even a group of faculty, without a clear vision for creating a standards-aligned physics teacher education program is unlikely to do so efficiently and effectively. Even with clearly defined goals, a program without proactive and creative leadership is unlikely to achieve the desired outcome. Leaders must clearly enunciate goals, design courses, marshal resources, model the appropriate form of teaching, align assessments, negotiate agreements, and do the required groundwork to get a very complex set of tasks accomplished in a timely fashion. If physics teacher education programs are to attract, retain, and graduate a growing number of high school physics teacher candidates, then such programs must be headed by one or more dedicated individuals who exhibit a passion for this complex task.

Change Principle 2: *If there is going to be significant, desirable, and lasting change in a departmentalized physics teacher education program, then an academic leader is needed who deeply understands the teacher preparation process.*

This change principle implies that physics teacher educators must known more than content knowledge if they are to do a good job of educating teacher candidates. Much more needs to be known about professional practice and how it is to be developed within physics teacher candidates. This includes findings from diverse areas such as physics education research, general science education research, and educational psychology research. The one thing that really counts in a teacher education program is whether or not the program graduates teacher candidates who will do what is expected of them upon graduation – use the best practices in the education of their own students. This can only be reasonably assured through a philosophically based, outcome-oriented education that uses authentic performance-based assessments to evaluate teacher candidates.

What teacher educators need to know and be able to do should be grounded in what teacher candidates need to know and be able to do. This consists of more than just content knowledge. National goals and standards have strongly converged in recent years on what it is that future teachers of science must both know and be able to do. Therefore, a common knowledge base has been established at ISU for the prospective physics teacher that is grounded in a wide range of science and teacher education standards. Consider the following factors that probably will make up any exemplary teacher education program: physics content knowledge (including a deep conceptual understanding), procedural knowledge including problem-solving skills, curricular knowledge, pedagogical knowledge, understanding what it means to be scientifically literate, understanding students, metacognition and student self-regulation, classroom management skills, communication skills, understanding of the relationship between teaching and learning, scientific and philosophical dispositions, social and technological context, learning environment, engaged learning, student assessment, self-assessment and reflective practice, critical thinking skills, technology of teaching, and professional responsibilities of teachers. Any one of these areas can be expanded dramatically, showing the broad nature of the knowledge needed by teacher educators. For instance, consider pedagogical knowledge and the many things that a teacher of teachers should know just in relation to this single topic. The teacher educator must help prospective teachers understand what constitutes effective teaching, and be able to distinguish true teaching practices from instructing, informing, and training. The teacher educator should have a demonstrable understanding of inquiry practices, cooperative learning, problem-based learning, modeling method of instruction, constructivism and concept change, learning cycles, metacognition, and student self-regulation. These are not things that the didactic university physics teacher will have in his or her teaching toolbox. Only years of self-directed professional development and reflection will lead a teacher educator to develop a good understanding of all these factors. In addition, learning how to teach these elements of the teacher knowledge base might require years of trial and error.

The Association for the Education of Teachers in Science (AETS) has created a set of professional development standards against which a teacher educator can self-assess [4]. These standards describe the major elements of knowledge at teacher education should possess and the types of activities that a science teacher educator should engage in if he or she is to be qualified to educator science teacher candidates: (1) knowledge of science, (2) knowledge of science pedagogy, (3) knowledge of curriculum, instruction, and assessment, (4) knowledge of learning and cognition, (5) research/scholarly activity, and (6) professional development activities. This set of activities suggests a second consideration, one related to the availability of time to complete the wide array of tasks required by a program administrator of a teacher education program.

Change Principle 3: *If there is going to be significant, desirable, and lasting change in a departmentalized physics teacher education program, then an academic leader is needed with adequate "release time" for the process of properly educating teacher candidates, for incorporating external standards, and for participating in and providing professional development activities.*

Consider the following additional aspects of program management that require significant contributions of time and energy if a exemplary physics teacher education program is to be developed: (1) completing accreditation processes; (2) creation and monitoring of clinical experiences; (3) supervision of student teaching; (4) creation of service learning projects; (5) assessing and documenting student competencies; (6) meeting with faculty colleagues to coordinate course offerings; (7) preparing and teaching model lessons; (8) maintaining contacts with area high school physics teachers; (9) teaching courses; (10) working with peers in science disciplines and the college of education; (11) offering professional development opportunities for cooperating teachers from area high schools (that is also important to helping develop a cadre of high school teachers willing to send prospective teacher candidates to institutions of higher learning); and (12) creation and redevelopment of a model physics teacher education program. Creating an exemplary and highly attractive PTE program is an ongoing process; and there are only a few models in development upon which work can be based[5]. For instance, the methods courses at Illinois State University have been taught and revised annually (sometimes very significantly) as a result of learning from "action research" and comments of students, cooperating teachers, inservice teachers, administrators, external evaluators, and accrediting agencies. The list of required work of the PTE program administrator goes on and on, but rarely does the tenure process take into consideration all of the time-consuming activities. Departments really need to provide time and credit (especially in the tenure process) to those faculty members who would become the teachers of teachers. Too often the tenure-granting process does not give adequate credit for this form of service; tenure decisions are often reached on the basis of scientific research and publications dealing with "hard" science, neither of which need be completed by a program coordinator intent on establishing an effective teacher education program. Creating a credible physics teacher education program takes a tremendous amount of time and energy, and unless appropriate credit is given for activities that necessarily must go with it, program coordinators might be reticent to spend time where it is most needed.

National science teaching and teacher preparation standards are a helpful guide to preparing an exceptional teacher education program. They provide a holistic view of teacher preparation, some elements of which can easily be overlooked by teacher educators who so often work in isolation, and some times don't have adequate experiences in the high school classroom. Embracing the recommendations of science teaching and teacher preparation guideline can provide not only criteria for assessing the quality of a teacher preparation program, but can also provide a logical basis for supporting programmatic revisions. This is especially so when the program is accredited by external agencies such as the National Science Teachers Association (NSTA) in cooperation with the National Council for the Accreditation of Teacher Education (NCATE) and the state board of education. While basic physics knowledge is central to the education of future physics teachers, according to the national science teaching and teacher preparation guidelines the nature of science, the context of science, and the social milieu of science also need to be part and parcel of a physics teacher candidate's education. Future physics teachers must embrace healthy scientific attitudes — objectivity, intellectual honesty, skepticism, and curiosity – among many other such things as ethical conduct. Teacher educators must develop and pass on to their students appropriate scientific attitudes. Attitudes give rise to thoughts, decisions, and actions. What teachers do as they present their lessons is rooted deeply in their attitudes about issues that concern them, their students, and society — balancing declarative knowledge with procedural knowledge, balancing expository teaching with inquiry learning, balancing depth of coverage with breadth of content, emphasizing learning over teaching, and knowing what values and knowledge are worth learning in light of national and state standards, and the needs of the student, the profession, and society. Teacher candidates must understand the basic assumptions and procedures of science. Not only should teacher candidate possess certain types of knowledge and attitudes, they must be able to demonstrate that they can use the information in a meaningful fashion. Science teaching and teacher preparation standards help programs to include goals and content that might otherwise be overlooked by a teacher educator working in isolation.

Standards-based teacher preparation might require that students demonstrate and/or articulate their knowledge, skills, and dispositions as they relate to state and national standards for science teaching, and a university's conceptual framework for teacher preparation. To this end, authentic performance-based assessments will be employed to ensure adequate preparation. In any physics teacher education program, performance-based assessment must be seen as a systematic approach of information gathering designed to assess both the knowledge and skills students demonstrate in creating the evidence of what they know and are able to do. Not only does a teacher candidate demonstrate the use of skill or knowledge to perform certain tasks, (s)he demonstrates the ability to perform tasks commonly encountered in authentic teaching situations. While traditional paper and pencil tests might answer the question, "Does the teacher candidate know how to do it?", performance-based assessment answers the questions, "Can the teacher candidate actually do it?" and

"How well does (s)he do it?" Authentic performance-based assessment will use authentic performance tasks that are directly related to the outcomes of teacher preparation.

Change Principle 4: *If there is going to be significant, desirable, and lasting change in a departmentalized physics teacher education program, then an academic leader is needed who is dedicated to and capable of quality teaching and effectively models it.*

Ideally, well-prepared high school physics teacher candidates will be philosophically oriented toward deploying and experienced in using the best practices of teaching identified by educational psychology and science education research. The list of best practices is extensive, and generally agreed upon. A sampling of the most fundamental best practices is provided (see Table 1). Most university-level methods of teaching of physics majors are not appropriate models of instruction for high school teaching because (as Linda Darling-Hammond and many others have repeatedly pointed out) *teachers tend to teach students in the same way they were taught.* Teacher candidates need to have the experience of being active learners. Emphasis on teaching must be placed on how to think, not merely what to think. To this end future physics teachers must be seen as guides to knowledge, and not merely as purveyors of knowledge. Rarely is a wide array of such approaches used in traditional university teaching in introductory courses for physics majors. (Fortunately, this is beginning to change[6].) Indeed, special courses in introductory physics for teacher education candidates that incorporate best practices would be the ideal according to Lillian McDermott[7]. This reorientation in teaching, from teacher-centered and didactic to student-centered and inquiry, requires a fundamental change of teaching philosophy and, indeed, in the very goals of teaching physics. Ideally, the teacher educator will have taught in an exemplary fashion for several years in a secondary-level setting before becoming a high school physics teacher educator. Alternatively, the physics teacher educator will have been continually engaged in professional development that will have resulted in university-level teaching strategies that are less didactic and more closely aligned will the sort of inquiry-based teaching called for in the previously cited national standards for teacher preparation.

Some of the Best Practices of Science Teaching

- Engaging students in active learning
- Using a constructivist approach
- Setting high expectations
- Providing and receiving feedback
- Accommodating student learning styles
- Teaching in a way that is consistent with student development
- Including real-world applications in the learning process
- Using individual and group motivation
- Making use of metacognition and self regulation
- Moving from concrete to abstract
- Requiring practice of learned skills
- Making use of multiple intelligences
- Establishing conducive learning environments
- Employing cooperative learning
- Encouraging student evaluation of alternative hypotheses
- Addressing conceptual goals and means
- Addressing misconceptions and concept change
- Promoting critical thinking
- Focusing on depth in addition to breadth of coverage
- Placing strong emphasis on interaction with phenomena
- Making clear and explicit linkage of representations to phenomena
- Using multiple representations of physical phenomena
- Assigning manageable tasks (zone of proximal development)
- Socratic questioning

Table 1. Some of the best practices of science teaching identified by education researchers.

Preparing teacher candidates to teach requires more than imparting content knowledge; it must also include a substantial amount of pedagogical and curricular knowledge. Successful teacher preparation does not consist of merely teaching a series of steps to be followed. Rather, teacher candidates must be educated to act on ethical principles that have been inculcated in them through several years of consistent, systematic, and comprehensive education. This requires the teacher educator to have a reasoned and consistent teaching philosophy, and a deep understanding of the teacher education process. Teaching philosophies need to embrace two fundamental beliefs: that prospective teachers must be prepared with a certain minimum of declarative and procedural knowledge, and that prospective teachers must possess dispositions that will allow them to think and operate in such as way as to be able to deal effectively with the changes of an uncertain future.

A faculty member who is strongly oriented toward research (applied, theoretical, and even educational) might not be the best person for the job of teacher educator, unless this faculty member has a nontraditional teaching style at the university level. Good high school teaching is usually quite different from university teaching. If done well, teacher candidate education, as well as high school teaching, will be inquiry oriented, and will help students construct knowledge and understanding through direct experience. Both will avoid "teaching by telling" that has been aptly described as "ineffective"[8]. Teacher candidate preparation will focus on content knowledge, intellectual process skills, and scientific dispositions so important to a scientifically literate populace. It will elicit and deal effectively with student preconceptions and misconceptions. It will help students to identify real-world problems, develop hypotheses, devise and conduct experiments, communicate effectively, use technology, work on cooperative teams, and make connections with real-world phenomena. University-level teacher candidate preparation will foreshadow a corresponding form of secondary-level, so it is important to teach teacher candidates in they same way that they will be expected to teach in the secondary school system.

Teacher educators must realize that teacher candidates will best learn how to teach by participating student-centered activities that model appropriate teaching and learning strategies. To this end, students will have the opportunity to frequently encounter over the course of several years of pedagogical preparation model high school physics lessons. In addition, a teacher educator's philosophy might address the fact that students learn best when they have a chance to construct their own knowledge, correct errors, and remediate deficiencies. Each time teachers present a lesson, he or she probably learns something about the educational process – how things can be improved the next time the lesson is presented. Those faculty who make a habit of reflecting on professional practice and taking the time necessary to change instructional delivery for the better will ultimately become the best teacher educators. The best teacher education faculty consists of individuals who model effective instructional practice and practice what they preach.

Change Principle 5: *If there is going to be significant, desirable, and lasting change in a departmentalized physics teacher education program, then a departmental faculty is needed that understands the procedures and worth of the physics teacher education, and supports the efforts of the physics teacher education academic leader.*

Most physics departments cannot long survive without undergraduate students. Departmental faculty must understand that undergraduates often come from high schools where the physics teachers are well educated, highly capable, and inspirational. This requires that even outstanding undergraduates be encouraged to go down the path of becoming high school physics teachers. Predatory practices by faculty who feel that physics teacher candidates are "too good" to "just become high school teachers" must be discouraged. Faculty members who act on the belief that the best students should go on only to graduate school and avoid the teacher education process are placing themselves in the unenviable position of eating their own seed corn.

Common sense suggests that students learn most when they have excellent teachers. Effective teachers possess a good understanding of the subject matter as well as the best methods for how best to teach it.[9] The need for having PTE major gain a good understanding of physics cannot be denied in the process of becoming a highly-qualified physics teacher. Nonetheless, advanced electricity and magnetism, quantum mechanics, solid state physics and similar advanced courses, while helpful in developing a holistic understanding of physics, are not necessarily prerequisites for teaching high school physics. The basics of physics, well understood from a conceptual viewpoint, is considerably more important. A sympathetic departmental faculty is required to accommodate this belief. Accommodation will take the form of relaxing requirements for advanced physics courses and provide more time in the teacher candidate's curriculum for conceptually and pedagogically-oriented courses.

Physics Teacher Education at Illinois State University

The PTE program at Illinois State University prepares students to teach physics and at least one other subject at the secondary school level. This program provides a thorough study of representative fields of physics, plus background in astronomy, chemistry, and mathematics. The required program of study integrates a minimum physics and chemistry concentration of 48 semester hours (s.h.) with a professional education sequence of 22 s.h., and the University's general education requirement of 45 s.h. All physics teacher education majors are currently required by state certification law to complete requirements for a second area of endorsement – usually chemistry. All students are advised to take courses adequate to ensure broad-field preparation in science. To this end they are encouraged to take two-course introductory sequence in biology for majors. Using the broad-field route to certification, students earn 56 s.h. in science; using the chemistry endorsement route, students earn 53 s.h. in science. A total of 115 clock hours of pre-student-teaching clinical experiences are associated with required professional studies and physics pedagogy courses for physics teacher education majors. Physics teacher education majors must complete 8 s.h. of student teaching in their content area.

Included among the required physics courses, PTE majors complete six pedagogically-oriented physics courses totaling 12 semester hours. Starting in the autumn of their sophomore year, students will take a 1-s.h. course Physics 209 – *Introduction to Physics Teaching.* This seminar course is based on a 25-clock-hour service learning project with an area high school physics teacher that allows candidates to see the practical problems of the physics teaching profession at the secondary level. This course helps students to determine if they truly want to become high school physics teachers. Students committing to the teacher preparation process then complete Physics 302 – *Computer Applications in High School Physics* (1-s.h. lab course) – during the autumn of their junior year. This course introduces students to computer-based science education hardware and software using a variety of inquiry-oriented laboratory activities. During the spring semester of their junior year, PTE majors take Physics 310 – *Readings for Teaching High School Physics* (3 s.h.). The focus of this course is on reading and discussing a variety of national and state science education standards, and reviewing the major findings of science education research. During the autumn of their senior year, PTE majors complete Physics 311 – *Teaching High School Physics* (3 s.h.). This course introduces many of the practical methods used in physics teaching, and gives students firsthand experience using a variety of pedagogical techniques including the Modeling Method of Instruction, problem-based learning, and lesson study (during which they develop and present to high school level students a model three-day inquiry lesson). Student teaching is restricted to the spring semester of the senior year. Before students begin to student teach, they complete a five-week, 3-s.h. course Physics 312 – *Physics Teaching from the Historical Perspective.* In this highly compressed course teacher candidates conduct experiment after experiment following *student performance objectives* and using inquiry approaches while also receiving an overview of the history of physics. During this time, and continuing throughout the student teaching practicum, candidates also take Physics 353 – *Seminar in Student Teaching* (1 s.h.). In this course students complete transitional clinical experiences that prepare them for student teaching, including a 15-clock our Social Context Project. In addition, students develop a professional teaching portfolio that documents with hard evidence the ability of teacher candidates to teach within the framework of both the National Science Education Standards and the University's conceptual framework *Realizing the Democratic Ideal.* Extensive details about all these courses can be obtained by reviewing their online syllabi at the following URL: http://www.phy.ilstu.edu/pte.html.

Over the past decade the tremendous changes that have occurred within the ISU Physics Teacher Education program have been based and were dependent upon the five change principles enunciated in this article. The first four change principles were, in large part, the natural consequences of the administration's creation of a full-time teacher education coordinator position, the selection of the appropriate person to fill that position, and a fundamental orientation toward supporting significant changes in the teacher preparation process. Following the vision statement of the coordinator of "build it and they shall come," the administration was very supportive of change process throughout the entire reform period. The coordinator shared his vision statement with the department's physics faculty during a summer retreat, and convinced them of the need for change. This was instrumental in getting curricular changes in the PTE sequence, and in getting proposals through the departmental curriculum committee. Physics teaching program coordinators who would like to see similar changes in their own departmentalized physics teaching program would benefit measurably from reflecting carefully on the principles noted in this article, and putting them into practice.

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[5] In addition the program at Illinois State University, there is also the evolving work of the PhysTEC program that is currently under development for instance.

[6] For instance, the *Workshop Physics* program of Priscilla Laws.

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