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JPTEO

INSIDE THIS ISSUE

JPTEO: MAKING A COMEBACK!

The last issue of *JPTEO* to appear was September 2003. Since that time I have received a significant number of e-mails asking something to the effect of, "When will the next issue appear?" Providing an answer to that question was not easy; it depended upon whether or not adequate suitable submissions were received for publication. *JPTEO* did not begin operating with a backlog of articles, and so just when the next issue would appear would always depended on the subsequent receipt of suitable articles for publication. Not that I didn't receive any articles! I did, in good number, and they came from all over the world. Unfortunately, the articles I received were not suitable for publication in this *Journal* given its orientation toward the preparation of physics teacher candidates and the professional development of in-service secondary-level physics teachers.

A fortuitous meeting between some of our readers and contributors at the Summer 2004 AAPT meeting in Sacramento, CA, convinced me again of the need for this *Journal*, and of the desire of our readers to again see it published on a regular basis. Dan MacIsaac, especially, encouraged me to continue with this work. He promised an article or two from him and one of his graduate students, and he has not disappointed. In this issue of *JPTEO* you will find an article by Chris Gosling who writes insightfully about curriculum and gender issues in the high school classroom. Dan MacIsaac writes about a new alternative certification program at SUNY-Buffalo State College that serves as a model for other institutions hoping to recruit, educate, retrofit, and retain secondary-level physics teachers. Graham Oberem and Paul Jasien write about their experiences with a Summer physics course for in-service teachers from which teacher educators most certainly can learn.

The last article to round out this issue of *JPTEO* reflects the work of the Illinois Section of the American Association of Physics Teachers (ISAAPT). The ISAAPT held a two-day special session during October aimed at repairing the Illinois high school physics teacher pipeline. An ad hoc committee was established at the Spring 2004 Section meeting for the purpose of reviewing and making recommendations in light of a serious high school physics teacher shortage being experienced in the State of Illinois. The committee was charged at looking at recruitment, preparation, and retention practices for high school physics teachers in Illinois. The findings based on a review of the literature and on two independent research studies - one dealing with physics teacher candidates and another dealing with in-service high school physics teachers - was nothing short of astounding. The Full Report of the Ad Hoc Committee on High School Physics Teacher Recruitment, Preparation, and Retention is a definite *must read* for anyone involved in the physics teacher pipeline. An Executive Summary, as well as PowerPoint presentations, data sets, and sundry other committee-related materials can be found on a special "Illinois model" website at the following URL: *www.phy.ilstu.edu/pipeline/.*

It is my continuing hope as Editor-in-Chief of this publication that *JPTEO* will become a lively and important forum for exchange is ideas and experiences by its readers. Only with authors submitting articles for consideration and publication, will this *Journal* likely reach that goal. I hope that you will help to spread the work about this fledgling *Journal*. Because I have several articles for consideration currently under review, I fully expect to publish yet another issue of *JPTEO* before the end of 2004.

I encourage each of *JPTEO's* readers to think seriously about contributing to the effort of achieving the goals of this publication. Detailed information about contributing to *JPTEO* can be found on the *Journal's* website at the following web address: *www.phy.ilstu.edu/jpteo/.* I look forward to hearing from you.

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JPTEO

Challenges facing high school physics students: An annotated synopsis of peer-reviewed literature addressing curriculum relevance and gender

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High school students have traditionally been taught physics by way of lectures, non-participative demonstrations, and cookbook laboratories. Not surprisingly, students leave the physics classroom with vague understandings of physics as a science and way of understanding our world. This problem is exasperated for female students, whose interests and culture are not addressed by typical examples and applications of physics. Challenges facing adolescent physics students can be addressed by cooperative learning in a supportive classroom culture and curricula tailored to meet the interests of all physics students in a concrete manner. Students' learning experiences can be drastically improved so they leave high school with a solid conceptual understanding of physics and its impact on their lives. In this manuscript, I present and discuss the classroom application of an extensive literature base addressing these above issues for use by working physics teachers and scholars of classroom physics teaching.

Introduction

Adolescents traditionally begin their formal study of physical science in middle school. They most often progress in the sequence of biology, chemistry, and eventually a senior elective if they continue their study of science (Lederman, 1998). Of these electives, physics is widely considered to be the most academically demanding. Even after instruction students often believe that physics is tremendously difficult and incomprehensible to a majority of the general population (Knight, 2004). The roots of this situation lie not only in the subject's demanding subject matter as a reputed "hard science," but also because of the abstract nature of physics as it is traditionally presented (via mathematical formalism).

Many former physics students remember physics as their "*worst* subject" (Knight, 2004), and nearly always these memories include images of a lecturer and associated experiments in a laboratory. Concerning the former image, Arons eloquently writes,

> …research is showing that didactic exposition of abstract ideas and lines of reasoning (however engaging and lucid we might try to make them) to passive listeners yields pathetically thin results in learning and understanding except in the very small percentage of students who are specially gifted in the field. (1997, p. vii)

Knight notes that the *standard* laboratory experiences wherein students "verify" theories or "discover" principles of physics produce little or no measurable benefit (2004, p. 20). Both lectures and standard laboratories have been shown to be flawed by current physics education research (PER) and science education research (SER). The story is often worse for females, whose interests were found to lie more in the natural and social applications of physics by Hoffman, Häussler, and Lehrke (as cited by Hoffman, 2002) and also by Stadler, Duit, and Benke (2000). Unfortunately, Hoffman, Häussler, and Lehrke (as cited by Häussler & Hoffman, 2002) found that these aspects of physics are seldom addressed by traditional curricula. Rather, when contextual references are made in the physics classroom they often focus on topics which are biased toward males such as sports, cars and military due to the historical prevalence of males in physics.

Over the past twenty-five years the field of Physics Education Research (PER) has come into its own and can readily supply a multitude of ways to combat the deficiencies of lectures and standard laboratories (Knight, 2004). Specific measures can be implemented to improve the appeal of physics to female students while retaining its lure for males. Hence, we will review applicable literature and draw from personal experience to suggest specific teaching techniques that can be used to lessen the above pedagogical challenges facing physics students of both genders. This literature is featured in the bibliography and in separate online bibliographies.

Literature Review

Students' attitudes toward science grow increasingly negative as they progress through school (Simpson & Oliver as cited by Kahle & Meece, 1994; Weinburgh, 2000) and even during college (Redish, Steinberg, & Saul, 1998). Though overall enrollment in high school physics has risen over the past decade (Neuschatz & McFarling, 1999), students' conceptual understanding of basic kinematics measured after traditional instruction, though marginally improved, remains deficient (Hake, 1998; Sokoloff & Thornton, 1997). Van Heuvelen (as cited in Knight, 2004) refers to the expository methods utilized in traditional physics instruction as, "…very ineffective—the transmission is efficient but the reception is almost negligible."

The situation is exacerbated for adolescent females who have more negative attitudes toward science and are less confident in their science abilities than males (Simpson and Oliver as cited by Kahle & Meece, 1994; Weinburgh, 1995). Though now females' enrollment in physics nearly equals that of males (Neuschatz & McFarling, 1999), girls and women do not achieve at the same level as their male peers (Bacharach, Baumeister, & Furr, 2003; Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000). The behavior of male physics students affects the learning process of females (Jones & Wheatley, 1990), as does the behavior of their teachers (Jones &Wheatley; Labudde et al.). Context has an important influence on female learning (McCullough, 2004; Pollina, 1995; Stadler, Duit, & Benke, 2000), but it has been found that topics and examples which interest females are also of interest to their male peers (Hoffman, Häussler, and Lehrke as cited by Hoffman, 2002). Curricula can therefore be differently constructed so as to meet females' needs while remaining appropriate for male students.

Physics curricula that challenge students while offering choices have been found to increase student motivation and encourage responsibility (Pintrich, 2003). Cooperative or collaborative classrooms have the ability to engage students and decrease the frequency of adverse gender interactions if an atmosphere of respect is maintained (Pollina, 1995). Cooperative classrooms encourage active learning, wherein engaged students construct their own meaning of concepts at hand (Knight, 2004; MacIsaac & Falconer, 2002) .A summary of this review can be found in Appendix A.

Applications

The findings from this literature can be directly applied to high school physics classrooms to provide an equitable and friendly learning environment for all students. Techniques to be considered include the following: offering students choice and promoting responsibility, creating a cooperative learning environment, fostering positive male adolescent behavior, equitable treatment of all students, and curriculum relevance to the real world. Specific suggestions will draw from the author's personal observations and accounts recorded by physics education researchers.

Choice and Responsibility in the Classroom

An example of a curriculum which offers students a choice in what they study is that exemplified by L. Hiller from North Tonawanda High School for his Regents and Advanced Placement (AP) courses (personal communication, Spring 2004). At the beginning of the semester, each pair of students in a laboratory section picks a theme to investigate for the duration of the semester. Available themes include sports, forensics, engineering, music, and computer investigations. Students select each five-week lab from a list centered upon the chosen theme. Each of these 5-week labs investigates a topic that has been covered in class discussion. General direction is given to each pair of students both at the beginning and throughout the five-week experiment, but in Mr. Hiller's six years of teaching no pair of students has performed an experiment in the same manner. At the end of the five-week laboratory, each pair of students presents their experiment to their section (L. Hiller, personal communication, Spring 2004). Each team is given five minutes and a whiteboard (MacIsaac & Falconer, 2004) to present their investigation and findings to the class. Data is typically presented in the form of graphs and diagrams and, if feasible, the apparatus is demonstrated. After their presentation, each team answers questions from their peers and the teacher, who is demanding not only with regard to what was presented but also considering alternative investigations and interpretations that could have been taken, data analyses, and further study.

Student responsibility can be easily effected by treating students as responsible adolescents (L. Hiller, personal communication, Spring 2004). At the beginning of each unit Mr. Hiller gives each student a packet of information and assignments to complete over the course of the topic. Advanced Placement (AP) students have the opportunity to complete extra problems from the textbook to compensate for lower marks earned during each topic. Additionally, students are given the due dates for their packets at the beginning of each topic. It is their responsibility to complete each topic by the date it is due; late assignments are not accepted. The author has observed the use of this technique and it is readily apparent that students are comfortable with this format. This technique works well for encouraging students to be responsible simply by treating them as mature individuals.

Creating a Cooperative Learning Environment

A cooperative or collaborative learning environment is one where students learn by working together to understand concepts rather than passively absorbing information. Traditional attempts to create such an environment have included the use of demonstrations and laboratory experiments. The author's personal experience has been that typical demonstrations do not deeply engage students. Standard laboratories have become the realm of rubrics and data sheets and are of little benefit to students (Knight, 2004). Conversely, a cooperative classroom is one where the instructor serves more as a facilitator of learning and students are active learners (Henry, 2001).

A cooperative classroom can be created in a number of ways (Knight, 2004). L. Hiller creates a collaborative environment by encouraging student participation through the use of collaborative classworks and laboratory experiments (personal communication, Spring 2004). W. Garlapo uses remote polling devices (personal communication, February 17, 2004) while Henry (2001), MacIsaac, and Falconer rely on whiteboards (2004). The precise method by which a teacher creates a collaborative environment is not critical, but it is important that this environment be friendly to females while offering all students the chance to work together and learn from doing rather than by being told.

Collaborative environments create a more social learning experience and are therefore more attractive to females by nature (Pollina, 1995). However, these benefits can be offset by poor group formation. Left to their own devices, students typically form groups with their friends. Possible arrangements of three students are: two males and a single female, two females and a lone male, or homogenous groups. Groups with two boys and a lone girl often result in the alienation or passivity of the solitary girl (K. Cummings, personal communication, April 17, 2004; MacIsaac & Falconer, 2004). To avoid this pattern, teachers need to find a way to eliminate this situation by creating groups themselves or by changing natural groupings.

Fostering Positive Male Adolescent Behavior

Detrimental male behavior in the physics classroom comes in several forms: the well known calling out (Kahle & Meece, 1994; Stadler, Duit, & Benke, 2000), commandeering superior laboratory equipment (Gillibrand, Robinson, & Osborn, 1999), and the dominance of both a teacher's time and attention (Robinson, 1996; Streitmatter, 1998). Teachers have traditionally tried to foster positive male behavior in a variety of ways.

One obvious way to deal with the calling out of male students is the creation of a rule explicitly forbidding this behavior at the beginning of a course. An alternative measure is that taken by Mr. Workman (Pollina, 1995), a teacher who created a collaborative environment only to have participation stifled by male students calling out frequently. He instigated a new rule where each student or group of students quietly wrote down the answer to the problem. Mr. Workman would then walk around the room and confirm whether the answer was correct or the student(s) needed to work further. Whiteboards (MacIsaac & Falconer, 2004) can serve as an effective medium for this interaction, creating a record of work that could be both easily examined by the teacher and shared with the rest of the class as desired.

The tendency of males to commandeer the best laboratory equipment and monopolize a teacher's time can be counteracted primarily by the teacher being aware of the interactions in the classroom. Additionally, a teacher could assign groups of students to a specific stations and rotate the superior equipment, but at the expense of creating additional work for him or herself. An alternative is letting students retrieve their equipment in a rotating order, assuming that they could identify the best equipment.

The last male behavior which can negatively affect adolescent learning of physics is the tendency to monopolize a teacher's time. Kelly (as cited by Stadler, Duit, & Benke, 2000) established that males "dominate the conversation between the teacher and students" in science classrooms (p. 418). Males have been known to cut ahead of female students who have been patiently waiting in line, which can result in female students feeling marginalized (Streitmatter, 1998). To avoid this, teachers needs to be particularly aware of which students have been waiting to speak with them and the order in which students arrived. Similarly, teachers should be aware of the time they spend with laboratory groups, regardless of the gender composition of the groups.

Equitable Treatment of All Students

Though Jones and Wheatley observed that "male teachers asked significantly more direct questions of students than female teachers" (1990, p. 866), they found no differences by student sex. However, Karp and Yoels found (as cited by Jones & Wheatley, 1990) that at the college level female teachers show no preference with respect to gender while male teachers ask more direct questions to male students. This inequality with respect to student gender may be the result of the character of answers that students typically provide. Teachers tend to appreciate responses from male students; the answers are usually succinct and can be modified to illustrate the teacher's point (Stadler, Duit, & Benke, 2000). Conversely, answers from female students are generally more drawn-out and specific in nature. Teachers who are insensitive to gender issues may resent these types of questions, for not only does it take longer to listen to a female student's answer, it is also more complicated to redirect a precise answer than the typical short statement of a male student (Stadler et al.).

A strategy for assuring all students are fairly called upon by a teacher is to buy a deck of cards for each class (K. Hover, personal communication, September 2001). Each student's name is written on a card, and equal opportunity is ensured through choosing students by cycling through the deck rather than having students raise their hands or by picking randomly. Variations on this technique can be created by creating categories rather than specific names, possibilities include a student "on the soccer team, born in July, whose first name begins with J, etc." A difficulty that can arise from the use of this technique is the assignment of a difficult question or problem to a low-achieving student. When this happens the author usually admits to the class that the problem is difficult and ask that the student give the problem a try, but also tell the student that they can "tag-team" anyone in the class (including the instructor if necessary) for assistance. When considering the deck of cards technique, it should be noted that every card in the deck cannot be used, and also that the teacher never makes a complete rotation through the deck during a class. The deck of cards is rather kept in order and the teacher picks up where he or she left off during the next class meeting.

Another way that teachers discriminate between students on the basis of gender is by the type of questions that they ask. Female students are more likely to answer open-ended questions while males prefer closed questions (Stadler, Duit, & Benke, 2000). This suggests that to equitably address a class, teachers should address different types of questions to students depending on their gender. However, open questions require the extension of concepts to ideas beyond what was directly considered in class. This process helps students form what Arons (1997) terms "operational definitions" of concepts and is crucial to their conceptual understanding of physics. Open-ended questions should be utilized as often as possible and directed to students of each gender with identical frequency. The use of open-ended questions should not merely occur during class, but should also be extended to assessments in the form of conceptual questions or essays (D. MacIsaac, personal communication, May 6, 2004). Both formats encourage females and males alike to apply their sociological knowledge of physics and represent a substantial step toward achieving a gender-equitable classroom.

Curriculum Relevance to the Real World

Physics teachers and textbook authors routinely use abstract scenarios or male-biased scenarios to give students an opportunity to apply concepts. However, "in comparison with the boys, the girls have less experience with and interest in physics and technology" (Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000, p. 148). This frequently puts female students at a disadvantage, for when real-world context is provided for physics examples and problems, it is often removed from female students' experiences.

Abstract problems are very efficient ways of providing an opportunity for students to apply their physics knowledge and problem solving skills. Unfortunately, they do not connect to students' lives and provide very little motivation for solving the problem. Rennie and Parker (as cited by McCullough, 2004) found that "…appropriate contexts make problems easier to visualize and more interesting." Problems of this nature have been termed "context-rich problems" (Context Rich Problems, n.d.) and serve the same purpose as equivalent abstract problems while allowing students to connect to the scenario. It is no surprise that Rennie and Parker (as cited by McCullough) found that students preferred concrete problems over abstract problems. Additionally, Hoffman, Häussler, and Lehrke (as cited by Hoffman, 2002) found that:

> Girls in particular respond very sensitively to a change of context. On average, girls expressed a relatively high interest in natural phenomena and phenomena that could be perceived by the senses. They placed a high value on references to mankind, social involvement, and the practical applications of theoretical concepts. (p. 451)

Context-rich problems provide a fertile ground for students to apply their knowledge while working toward a definite goal and maintaining a sense of how the current topic applies to their environments, and should be used whenever possible. However, the nature of these problems needs to be tailored to meet the needs of all physics students.

Physics teachers and textbook authors have often relied on the mainstays of bullets, hockey pucks, rockets, and race cars to illustrate physics concepts or describe scenarios for problems in terms that students can relate to. Indeed, two of the most popular textbooks in the nation for high school students (Neuschatz & McFarling, 1999) show few examples that are specifically targeted toward female students. Chapter 2: Linear Motion of Hewitt's *Conceptual Physics* (1998) includes numerous examples to cars, planes, and basketball players, but only one reference to ballet. The equivalent chapter in Halliday, Resnick, and Walker's *Fundamentals of Physics* (2001) contains references to cars, trucks, particles in motion, baseballs, armadillos, elevators, and manned projectiles going over Niagara Falls. While the last three examples are not gender biased, the preceding examples are geared toward males. Though textbooks have begun to substitute female subjects into their problems, the scenarios that are presented remain predominantly masculine. This male bias extends even to our assessments, from standard evaluations (Kahle & Meece, 1994) to the Force Concept Inventory (FCI), the current backbone of conceptual mechanics assessment (McCullough, 2004).

As McCullough (2004), Pollina (1995) and Stadler, Duit, and Benke (2000) found, context plays an important role in students' performance with regard to gender. While not advocating a switch from a male bias to a female, it appears that any contextual references made should be at least neutral. There is also evidence that contextual references friendly to females do not hinder males' performance on assessments (McCullough), and Hoffman, Häussler, and Lehrke (as cited by Hoffman, 2002) found that "what is interesting for girls is also interesting for boys, but not necessarily vice versa" (p. 451). Häussler and Hoffman found that "adapting the curriculum to the interests of girls is also advantageous for boys" (2002, p. 885). Since the number of females in physics classrooms is nearly equal to that of males (Neuschatz & McFarling, 1999), both curricula and assessments should be modified to cater to interests of both male and female students. This can be done by including examples of household objects whenever possible, and not just rifles and cars. Female-friendly objects such as those McCullough used to create the Revised FCI (RFCI) would be excellent sources. These may include objects rolling off of a table, shopping scenarios, safety scenarios such as the bicycle helmets described by Häussler and Hoffman (2002), or female oriented activities such as gymnastics or ballet. Also, an effort should be made to connect topics not only to students' experiences, but also to instill an awareness of how the topic affects the rest of the world to embrace female ways of thinking (Stadler, Duit, & Benke, 2000). This will help females feel that the topic is important to their lives and to see how it fits into their global patterns of learning.

Conclusion

Adolescent physics learners face numerous significant challenges in acquiring a robust conceptual knowledge of physics. Though physics will always remain an intellectually challenging subject, it is apparent that as it is presently taught there are numerable distractions and unnecessary challenges resulting from the manner of instruction and an insensitivity to gender issues. Published literature suggests a variety of solutions, summarized in Appendix B. There are many ways to reduce the academic challenges facing physics students, particularly with regard to addressing gender inequalities by reforming classroom culture. By becoming cognizant of gender issues and creating both a cooperative and female-friendly classroom environment, future adolescent physics students of both sexes will better rise to the challenge and enjoy the fulfilling experience of the rich and powerful conceptual understandings of physics.

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Appendix A

Literature review of academic challenges facing adolescent physics learners

Observation or Conclusion	Researcher(s)
Students hold increasingly negative attitudes toward science as they progress through secondary school and into college	Simpson & Oliver as cited by Kahle, J. B., & Meece, J. (1994) Weinburgh, M. H. (2000) Redish, E. F., Steinberg, R. N., Saul, J. M. (1998)
Physics instruction fails to increase or even maintain student interest in physical science	Broome, P. (2001) Häussler, P., & Hoffman, L. (2002)
The percentage of students enrolled in physics is at a maximum	Neuschatz, M., & McFarling, M. (1999)
Traditional instruction does not lead to conceptual understanding	Hake, R. R. (1998) Van Heuvelen as cited by Knight, R. D. (2004) Sokoloff, D. R., & Thornton R. K. (1997)
Females hold more negative attitudes toward science and are less confident in their scientific abilities than males	Simpson & Oliver as cited by Kahle, J. B., & Meece, J. (1994) Weinburgh, M. H. (1995)
Females are no longer a minority in physics classrooms	Neuschatz, M., & McFarling, M. (1999)
Females achieve at lower levels than males do in identical physics classrooms	Bacharach, V. R., Baumeister, A. A., & Furr, R. M. (2003) Labudde, P., Herzog, W., Neuenschwander, M. P., Violi, E., & Gerber, C. (2000)
Male behavior affects the way that females learn	Jones, M. G., & Wheatley, J. (1990)
Context is of particular importance for female learners	McCullough, L. (2004) Pollina, A. (1995) Stadler, H., Duit, R., & Benke, G. (2000)
Topics that interest females also interest males	Hoffman, Häussler, and Lehrke as cited by Hoffman, L. (2002)
Teachers treat students differently by gender, affecting their learning processes	Jones, M. G., & Wheatley, J. (1990) Labudde, P., Herzog, W., Neuenschwander, M. P., Violi, E., & Gerber, C. (2000)
Curricula offering choices and challenges motivate students and foster responsibility	Pintrich, P. R. (2003)
Cooperative classrooms engage students and have the ability to decrease the frequency of adverse gender interactions	Pollina, A. (1995)

Appendix B

A summary of recommendations and suggested implementation techniques for introductory physics teachers

Recommendation	Issue of Interest	Possible Techniques for Implementation
Offering students choice and responsibility	Give students choices	Modified laboratory curriculum (Hiller)
	Promote student responsibility	Treat students like adults
Create a cooperative learning environment	Increase student interaction and engagement	Classworks and small-group activities Laboratory experiments (in groups or as an entire-class activity) Remote polling devices Whiteboards
Equitable treatment of students	Unequal distribution of questions	Deck of cards
	Address questions to all types of students; promote conceptual learning	Open-ended questions
Fostering positive male adolescent behavior	Reduce frequency of calling out	Rules for answering questions Write down answers to questions (whiteboards)
	Equitable lab equipment distribution	Assign groups to tables that already have equipment Regulate the order in which lab groups get equipment Each pair of students works on a different lab (Hiller)
	Equitable Time Distribution	Awareness of students waiting Limitation on time spent with each group
Relate curricula to the real world	Give contextual references that all students can relate to	Include contexts that both females and males are familiar with such as those involving household items or common activities

A new model alternative certification program for high school physics teachers: New pathways to physics teacher certification at SUNY-Buffalo State College

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We describe the need for development and deployment of a new model graduate level alternative certification program for physics teachers at SUNY-Buffalo State College. The Masters of Science Education (Physics with NYSED Transitional B Certification) program accommodates science and engineering professionals with appropriate bachelors degrees who wish to change career paths into physics teaching. The alternative certification program is distinctive in that candidates minimize their income disruption and bypass student teaching through an intensive full time Spring-Summer introductory component leading to NYSED Transitional B Certification, followed by paid, mentored teaching employment and evening coursework for two calendar years. This alternative certification program is made possible through physics teachers' summer academy courses, supplemented by regular semester evening course and online offerings. Courses are shared with a second new program - the Masters of Science Education (Physics), which serves already certified science teachers (usually in subjects other than physics) who wish to obtain a master's degree for permanent teacher certification and usually teacher certification in a second discipline — physics.

Introduction: National and New York State Demand for Physics Teachers

Scholars of teacher preparation have observed that currently there is *not*, in fact, a general nationwide shortage of teachers in the United States (Darling-Hammond, 2000; 2001). In general, there are adequate numbers of prepared and certified teachers to meet most of the nation's needs, with waiting lists of teacher applicants for positions in affluent suburban districts, yet "we face shortages of people willing to work at the salaries and under the working conditions offered in specific locations" — in rapidly growing, *rural* and *urban* areas (Darling-Hammond, 2001). Real teacher shortages do exist in a few subject fields — most particularly in special education, mathematics, *physics*, chemistry, and Spanish, in order of national demand (AAEE, 2003). Teacher shortages in science and mathematics subjects are exacerbated by the fact that these fields require knowledge and skills in demand by other noneducational employers at higher rates of compensation (Darling-Hammond, 2001).

Currently, there is intense demand for highly qualified and certified high school physics teachers both nationally and in New York State. Recently, US high school physics enrollments have experienced continued growth leading to fifty-year high enrollment levels (AIP, 1999; Neuschatz & McFarling, 2000). Fewer science teachers major in physics than in the other science disciplines, and many physics teachers (particularly urban and rural teachers) only teach physics a small percentage of the time compared to other sciences (Neuschatz & McFarling, 2000; UTC, 2000). Only about one-third of all physics teachers received a major (or graduate degree) in physics or physics education, and adding physics minors only raises this total to 45% (Neuschatz & McFarling, 2000). As a result, the claim has been widely made that nationally more than half of all physics teachers (AIP, 1999) are actually teaching *out-of-field,* – that is without a degree or a minor in physics or physics education (Ingersoll, 1999; CSMTP, 2001). This definition must be tempered by recognizing that 61% of public and 27% of private high school physics teachers are in fact state certified to teach physics, though state certification requirements vary widely and may be grandfathered from weaker historical requirements. The recent US federal law concerning K-12 education known as the *Elementary and Secondary Education Act (ESEA) of 2001 (No Child Left Behind or NCLB)* (US Department of Education, 2003) has directed changes to teacher certification practices but has not standardized this issue.

Partially in response to national NCLB legislation, the New York State Education Department (NYSED) recently intensified teacher certification and high school science graduation requirements (NYSED, 2000), established a new Regents' physics core curriculum (NYSED, 2001) and revised the statewide Regents' Physics exam, incorporating increased levels of conceptual understanding (Zawicki, Jabot, Falconer, MacIsaac, Henry & Fischer, 2003). This has further increased the NY demand for high school physics teacher certification (Willie-Schiff, 2002), particularly for those non-physics certified science teachers who have been teaching physics (so-called cross-certification candidates). NYSED physics certification requirements were increased to include thirty credits in physics

(NYSED 2004) and the successful completion of a *Content Specialty Test* in Physics (NES, 2002). In 2001-02, NY State exceeded national norms for certification prevalence (Table 1) and 65% of the 1700 NYS high school physics teachers were certified to teach physics (Willie-Schiff, 2002). However, another 21% of those teachers were not certified, were temporarily certified or were not recognized by the system, and an additional 14% of the total physics teacher pool was working under provisional certification. Following either initial or provisional certification, teachers must complete an approved Masters degree, depending upon the teacher's initial certification date, within either three or five years to earn full professional certification in NY (NYSED 2004).

New York physics teachers lead the aging and imminent retirement trends of the general US national science and mathematics teacher population. A great many NY physics teachers are nearing retirement — of the 65% of NY teachers with permanent certification, 728, (43% of the entire NY HS physics teaching population, or *over half of the 2002 NYSED physics- certified HS physics teaching population*) are over the age of fifty. Estimates of prospective retirements are not available, but these data strongly support the conclusion that there will be a significant number of retirements over the next decade. NY acutely needs a larger pool of physics teachers including new physics teachers from traditional preparation paths, career-changer becoming physics teachers from non-teaching technical and engineering professions, and teachers cross-certifying into physics from other teaching disciplines. This last group is, in fact, already teaching physics and forms a significant needful population.

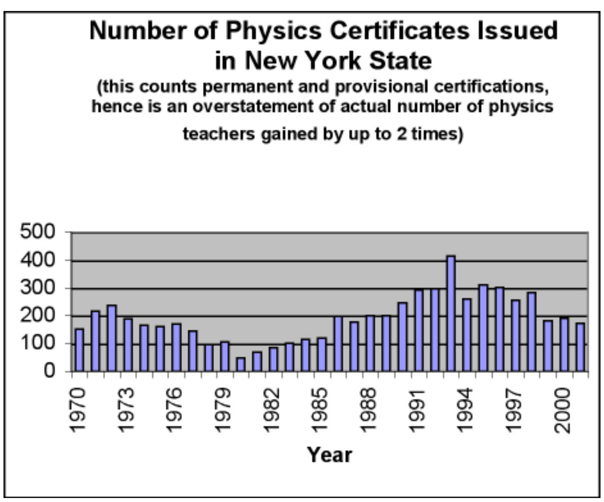
While under-represented minority high school physics student enrollments are increasing along with the entire population, the enrollment gap between under-represented and majority students in physics courses remains 'well-entrenched.' Alarmingly, non-white physics teachers are 'virtually non-existent' (AIP, 1999). About a quarter of current high school physics teachers are female (Ivie & Stowe, 2000), and about 47% of high school physics students are female (AIP, 1999). In conclusion, there is a tremendous demand for certified physics teachers, particularly in rural and urban core schools, and most acutely for certified minority physics teachers both nationally and in NY state.

Alternative Teacher Certification

Irregular certification has most recently become a political 'hot button' issue due to calls by the Bush administration for effectively dismantling teacher education systems and redefining teacher qualification to espouse alternative certification (US Department of Education Secretary's Annual Report, 2002, p21; Darling-Hammond, 2002; Darling-Hammond & Youngs, 2002).

Alternative certification refers to a teacher certification program that differs from standard college programs of teacher preparation, usually by avoiding the extended guided field experience of student teaching. Alternative certification is frequently insufficiently differentiated from emergency certification, which usually refers to a complete waiver of any teacher preparation to obtain a teacher who is otherwise unavailable. Other certification routes intermediate to these exist, particularly individual (transcript) evaluation in NY.

Cogent and compelling scholarly critiques of irregular certification pathways exist, in particular Darling-Hammonds' research on alternatively and emergency certified teachers in New York City during 1997-8. These teachers were disproportionately hired to teach the least advantaged minority, lower-income urban students (a disconcertingly common characteristic for such irregular teacher hiring and preparation practices). Darling-Hammond received survey responses from some 3000 of a possible 9000 NYC teachers hired within their first three years in 1997-98 (many missing respondents were no longer employed by NYC schools), and discovered that some on temporary or emergency certification had little more preparation than brief summer workshops (Darling-Hammond, 2002; Darling-Hammond, Chung & Frelow, 2002). These candidates included those from several pathways, including *Teach for America (TFA),*



NYS Physics Teacher Data for the 2001-02 school year

		FTE	# Classes	Ave FTE/Teacher	% of total (FTE)
Total number of physics teachers	1691	783	3132	0.46	100.0
Physcis teachers with no physics certification, temporary certification, or not in system	351	132	528	0.38	16.9
5 yr provisional & CQ	242	126	504	0.52	16.1
permanent certification	1098	525	2100	0.48	67.0
Over age 55	454	221	884	0.49	28.2
Over age 50	728	337	1348	0.46	43.0
Regents Physics		584			74.6
Second Year Physics		2.6			0.3
AP Physics		106			13.5
Other		90			11.5

Figure1 and Table 1: *Select Data Describing The New York State Physics Teacher Shortage And Population Inversion By Age* the *Peace Corps, Troops to Teachers* and *Teacher Opportunity Corps* – who almost universally (90%-100%) left the profession by their third year. This compares to a third year departure figure of about one-third of traditionally trained teachers and about 10% of teachers prepared in extended five-year programs that include a full year of student teaching (Darling-Hammond, 2001, p15). Darling-Hammond then went on to do a detailed cost analysis on both the longer-term financial and education costs of such 'drive-by' teacher hiring policies, including a cost analysis of differing variables in student achievement. Darling-Hammond constructed a strong case that short-term hiring policies are costly in the long term, and that dollars spent upon teacher preparation are one of the most cost-effective predictors of student achievement.

However, Darling-Hammond identified some very few alternative certification programs as quite successful – those few incorporating extended teacher mentoring and induction support interwoven with course work and clinical training (Darling-Hammond, 2001). Furthermore, she explicitly called for the creation of "*extended teacher education programs with year-long internships in … high quality alternative pathways at the post-graduate level… for mid career changers…*" (Darling-Hammond, 2000, p35).

Researchers note that though alterative certification teachers leave the profession at higher rates than do traditionally prepared teachers, they are preferentially hired by Local Education Authorities (LEAs – schools and districts) as new teachers and are far more likely to seek immediate employ after certification. Notably, up to 30-40% of new teachers graduating from traditional certification programs are not immediately employed as teachers. Due to this common hiatus in accepting employment, of all 15,000 teachers prepared in Texas in 1995, the alternative certification program graduates still held the highest percentage of employment after five years despite having the highest attrition rate from the profession as working teachers (Harris, Camp and Adkinson, 2003). Alternative certification candidates are much more dedicated to finding immediate employment than are teachers from other certification, a fact confirmed by Darling-Hammond (2000). Shen (1998, 1999) further found that alternative certification programs recruit significantly more minority teachers than traditional programs; these teachers are significantly more likely to be employed in urban schools serving minorities, are significantly more likely to teach mathematics and science and are significantly more likely to have considerable business or military experience.

Although problematic, alternative certification programs can be done well, and can provide a viable pathway to physics teacher preparation. Alternative certification program candidates bring uniquely attractive backgrounds and interests to address needs for under-represented teachers sought by schools. Alternative certification programs can address needs not adequately met by traditional programs.

Overview of the Two BSC *M.S.Ed. (Physics)* Programs

The BSC *M.S.Ed. (Physics)* programs are summarized in Figure 2. Admissions require either current NYSED secondary science certification (the right hand side of Figure 2), or for alternative certification (the left hand side of Figure 2), a bachelor's degree meeting NYSED language and content requirements for physics certification, and successful completion of the NYSED state teacher competency examinations (LAST and the Physics Content Subject Test) required for physics teacher certification. Certified participants do not have to take any additional education courses or workshops, unlike alternative certification candidates who must take an early field experience and some education courses before they can be awarded the Transitional B certification and can accept classroom employment.

Alternative certification candidates typically complete their initial employment requirements through full-time enrollment in the spring semester, followed by an intensive summer academy, then teach the following school year under Transitional B certification under both BSC Physics mentorship and an intense LEA induction program. Alternative certification candidates can be in the classroom employed as full-time transitionally licensed teachers after as little as two semesters of full time student study (one spring and one summer semester), and we have had several candidates succeed with exactly this arrangement.

During the regular academic year, *M.S.Ed. (Physics)* candidates also take some combination of evening and distance education courses. Although coursework for the alternative certification program can be completed in the following summer academy, the NYSED Transitional B certification agreement requires a minimum of one full year of intensively mentored teaching experience for regular teacher licensure.

M.S.Ed. (Physics) program candidates who are already NYSED certified in another subject can add physics certification and complete their program in about four semesters if they enroll in two successive summer academies together with the regular fall and spring semester evening and web courses. Each summer, 18 credits of summer academy courses are offered for teachers (including six credits for K-8 teachers), with a minimum of 6 credits of evening classes (9 cr. this academic year) between regular Fall and Spring semesters. We have also placed some few of these offerings online as appropriate (E.g. PHY500 and PHY690) and we are creating online support materials (and local tutorials) for NYSED Physics CST exam preparation. This greatly extends statewide reach for our coalition and meets teacher demands.

We accept transfer credit and some of our downstate candidates have taken some of the online course offerings for graduate credit in physics from the NTEN/NSTA and University of Virginia programs in particular (NTEN, 2004; University of Virginia, 2004).

The graduate physics courses for these programs include a mixture of undergraduate physics content and graduate level physics pedagogical content knowledge (physics and science education research PER and SER findings, and science teaching methods), presented at an undergraduate mathematical level. Physics content is largely shaped by research findings and state requirements, and frequently departs from traditional physics

The *M.S.Ed.-Physics* degree programs at SUNY- Buffalo State College

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	M.S.Ed.-Physics (NY Alternative Certification via Transitional B) New teacher cert for Science/Tech/Engg/Math professionals	M.S.Ed.-Physics (usually second NY Cert) STEM teacher cross certifies to physics	
Program admission requirements	Physics or related bachelor's degree	NYS certification in a secondary science	
	3.0 GPA	2.5 GPA	
	18 cr of non-physics science	n/a	
	language req	n/a	
	NYSED Tchrs exams (LAST & Physics CST)	n/a	
	3 written references & interview	3 written references & interview	
Coursework			e = existing course; n = 2002 new course; r = 2002 revised course
Seminar (3cr)			
PHY500: Physics Education Research Seminar	Y	Y	r
Physics Teaching Methods (6cr)			
PHY510: Process Skills in Physics Teaching (6 cr)	Y	Y	r
w/ 40h early field experience grades 7-12	Y	N	
Physics Content w/Model Pedagogy (12cr)			
PHY620: Powerful Ideas & Quantitative Modeling: Force, Motion & Energy (6cr)	Y	Y	n
PHY622: Powerful Ideas & Quantitative Modeling: Electricity & Magnetism (6cr)	Y	Y	n
Project (3cr)			
PHY690: Research Project	Y	Y	e
Electives			
PHY518: Wave Phenomena and Optics	6cr	9cr	r
PHY520: Modern Physics			r
PHY525: Nuclear and Particle Physics			e
PHY616: Advanced Dynamics			e
PHY618: Advanced Electricity and Magnetism I			e
SCI527: Current Topics in Science			e
SCI632: Curricular Trends in Science Teaching in the Secondary School			e
SCI664: Teaching Science with Media			e
SCI685: Evaluation in Science Education			e
Or other courses by advisement			
Teacher Cert Requirements			
EXE633: Adapting Content Area Instr for Children & Adolescents w/Disabilities	Y	N	e
EDF529: Adolescent Psychology	Y	N	e
EDU417: Adolescent Literacy	Y	N	e
plus one of			
EDU416: Teaching Literacy in Middle and Secondary Schools	3cr	0cr	e
EDU609: Improving Reading in the Content Areas			e
NYSED 52.21(b)(3)(xvii)-regulated college mentored physics teaching experience			
paid employment for 1 year w/ NYSED Transitional B Certification	Y	N	
Total number of required credits:	**42cr**	**33cr**	

Figure 2: The *M.S.Ed.— Physics programs at SUNY- Buffalo State College.*

course curricula – for instance there is essentially no treatment of thermodynamics, while there is a significant treatment of modern physics dictated by the state via PER-informed curricula.

The two 600-level summer academy courses are particularly intensive fifteen day workshops modeled after the nationally renowned *Modeling Physics* workshops held at Arizona State University – in each course approximately thirty participants work through PER-informed curricular activities in both student and teacher roles. Besides Hestenes' distinguished and well-researched *Modeling Physics* curriculum, activities from the AAPT's *Powerful Ideas in Physical Science (PIPS)* and Goldberg's *Constructing Physics Understanding (CPU)* curricula also inform these workshops (Wells, Hestenes & Swackhamer, 1995; Hestenes, 1987, 1993; Modeling Physics Group, 2004; AAPT, 2004; Goldberg 2000). PHY510 is a locally developed workshop course originally intended to support new teachers who were assigned to teach physics without physics certification, and focuses on meeting NYSED requirements through activities NY master physics teachers have selected on an *ad-hoc* basis, leavened with formal PER and SER touchstone activities.

Finally, though not accepted for *M.S.Ed. - Physics* program core credit, the summer academy includes at least one offering for K-8 teachers of physics, usually PHY507, a course dedicated to the appropriate NYSED standards incorporating the above curricula plus Goldberg's *Physics for Elementary Teachers* (Goldberg, 2004) curriculum activities, and frequently incorporating a PER or SER component by blocking it with a second graduate course in science curriculum research for K-8 teachers, EDU671.

The other two notably unique courses are PHY500 —an online seminar of PER readings and findings, and PHY690 — a terminal masters' project producing a manuscript contributing to the physics teaching community, most of which are web-published, but some of which will be published (shortly) in the peer reviewed literature. This last course is particularly challenging for instructor and candidates, but very rewarding. These last two, together with several topical courses, are offered during the Fall and Spring semesters.

Lessons Learned

There has been considerable demand for our *M.S.Ed. (Physics)* programs. We have stabilized our program size at approximately forty candidates by restricting acceptances to only the best qualified and most likely applicants. Since the programs were inaugurated in fall and summer 2002, three candidates have graduated, with two more to graduate shortly. About two thirds of all candidates are certified working teachers who are seeking either certification to physics and / or a permanent license, with a small few candidates who don't require physics certification or a masters' degree for permanent certification who are simply improving their physics teaching skills. The remaining third of the candidates are alternative certification students. The Physics Teachers' Summer Academy acts as a recruiter for the *M.S.Ed. (Physics)* programs, attracting about a hundred teachers per summer to the BSC campus, with another twenty-five to fifty teachers attending the monthly Saturday morning alliance meetings of the Western New York Physics Teachers' Alliance (WNYPTA, 2003) supplementing the recruiting pool and candidate support network.

The non-certification *M.S.Ed. (Physics)* candidates are mostly (65%) HS science and math teachers seeking certification in physics, with some (30%) already holding initial physics certification and a small number (5%) of elementary and middle school teachers (usually those with minors in physics) seeking secondary physics certification.

Second subject certification for science teachers via a discipline-specific masters degree intended for teachers is growing common and greatly improves employment flexibility for NY science teachers. A very few certified candidates have no NYSED need for another masters' degree and simply want to improve their physics teaching; we tend to attract these candidates to satisfy their NYSED graduate physics content credit requirements or to attend physics alliance meetings, and they sometimes stay for the reformed teaching and student-centered pedagogy. Although we have essentially no minority candidates to date, we have almost 10% women and we are trying to recruit both populations. We are particularly pleased to have candidates who are working teachers in urban, high-needs school settings, including one starting a physics program at her school which presently does not offer physics. We hope to have these candidates support future recruiting of undergraduate student and graduate student physics and physics education candidates from amongst their own students and colleagues.

The remaining third of our *M.S.Ed. (Physics)* candidates (fourteen) are career-switching technical professionals; of these all save three (77%) hold bachelors' degrees in various fields of engineering. Most are young men who have practiced engineering for several years and are seeking more rewarding careers with greater employment stability. The other three include two alternative certification (AC) candidates with a B.S. in physics and a Ph.D. physicist switching careers to teaching. These AC candidates are usually altruistic and reflective about their reasons for career change (we are not admitting simple economic refugees), and some have worked as substitute teachers, which is something we strongly encourage. Our AC candidates are almost universally looking to move directly into the classroom as quickly as possible, want to minimize their time in university classrooms (they seem particularly hostile to education coursework) and want to minimize the financial disruptions due

Checklist for *M.S.Ed. (Physics)* with NYSED Transitional B Certification Candidates

1. Admissions Requirements. To be *fully* accepted (not *provisionally*; we accept both) into the M.S.Ed. program:
- bachelor's degree in physics or related area (engineering)
- cumulative GPA of 3.0 / 4.0
- minimum of 18 hrs in 2 other teachable sciences (we prefer 6 cr CHM, 6 cr BIO, 6 cr ESci)
- one year of college or two years of HS foreign language
- passing scores on LAST and Physics CST NYS teacher certification exams; see <http://www.nystce.nesinc.com/> for arrangements. Exams require registration 2-3 months ahead to avoid late fees; 2 weeks in advance is "emergency" registration
- full application packet including three letters of reference

2. Introductory Component. For the NYSED Transitional B Certificate, you must complete all of the above and add the following before you are permitted to take a job:
- 200 clock hours of pedagogical core study; usually by PHY510 and PHY600 (or PHY622) from the summer physics teacher's academy. Clock hours = instructor contact hours.
- 40 clock hours of field experience; with selected certified local area physics teacher during regular school semester hours - see Field Experience Agreement Form at <http://physicsed.buffalostate.edu/programs/pgmdox/>
- EDF529 Adolescent Psych (or equivalent)
- EXE500 Individuals with Special Needs (or equivalent)
- professional workshops available through <http://www.buffalostate.edu/academics/cenc/>:
    - Child Abuse Workshop
    - Drug and Alcohol Workshop
    - Fire and Arson Workshop
- start career planning / placement and professional folder process on 3rd floor Grover Cleveland bldg or alternative <http://www.buffalostate.edu/offices/cdc/index.html>
- contact BSC certification officer for application / completion / approval of NYSED Transitional B Certification <http://www.buffalostate.edu/depts/teachercert/>
- get a job! :^)

3. In-service Component. To receive the NYSED Transitional B Certificate, the above must be *completed* and the following *undertaken* to retain transitional certification and continue towards the appropriate NYSED provisional / permanent or initial/professional certificates:
- good academic progress in the remaining MSED courses listed in the program catalog also listed at <http://physicsed.buffalostate.edu/programs/MSEDPgms.html>
- completion of the remaining required professional workshops (HIV/AIDS and SAVE; available through <http://www.buffalostate.edu/academics/cenc/>) and remaining NYS teacher certification examinations (ATS-W; see <http://www.nystce.nesinc.com/>)
- appropriate mentored teaching in the grade and subject (physics) for which certification is

Table 2: *Checklist for Alternative Certification Candidates*

to full time student enrollment. One exception to this is still working as an engineer and taking one program course per semester. Like many traditionally prepared teacher candidates, they also resent the unpaid-while-paying-tuition nature of traditional student teaching.

Alternative certification programs incorporating physics content for these individuals are quite rare, though these candidates could readily locate other certification programs without physics content such as an *M.Ed.* or *M.S.Ed. (Science)* or a post-baccalaureate non-degree program in general science teaching, and we don't believe we are cannibalizing such programs. Only one AC candidate holds a Buffalo State Physics department undergraduate degree. Alternative certification candidates present unique issues in physics teacher education; our candidates sometimes hold inappropriately optimistic estimations of their subject expertise and strong, under-informed preconceptions of good teaching practices. A reflective exposure to SER and PER instruments and literature, and explicit instruction via student-centered constructivist reformed teaching methods helps them address these issues. Abd-El-Khalick (2003) has referred this as the expert-novice-expert problem; AC candidates need to recognize that their expertise in one area doesn't map onto a new subject area before they can progress in their development as teachers. Traditional undergraduate teachers in preparation move through a novice-expert development cycle (often holding naive images of good teaching), and experienced teachers from other science disciplines may need to move through a different kind of expert-novice-expert developmental sequence with regard to acquiring new pedagogical skills in inquiry-based, student-centered, constructivist (reformed) teaching (MacIsaac, Sawada & Falconer, 2001; MacIsaac & Falconer, 2002).

Because the AC candidates require monthly observation visits from a faculty member for a year and incumbent travel time, the program is currently limited to approximately this number, and we no longer advertise the AC program except by word of mouth and posters at state science conferences. We do advertise the non-certification program in yearly mailings to physics departments and high schools statewide. We currently have no out-of-state candidates, though we have a very few out-of-state Summer Academy registrants every summer.

These forty candidates represent maximum capacity for a program dedicating approximately 1.0 FTE year round faculty without research release (three graduate courses each semester year round). To staff these programs at SUNY-BSC, one new full-time faculty member was hired and is supported by another faculty from physics and faculty from two other departments to teach these course offerings. In particular, the summer academy courses require additional instructional personnel, both BSC faculty and master physics teachers, making the programs extremely faculty time intensive. Despite receiving NSF supplementary funding (for candidate scholarships and support), the *M.S.Ed. (Physics)* program courses alone are run on a cost-recovery basis; BSC makes money on the summer academy courses in particular (six graduate credits of in-state tuition cost approximately $1800). Summer academy courses routinely fill to capacity and students are turned away. SUNY- Buffalo State College is historically a teacher preparation institution, famed for preparing high-quality teachers, and successfully competes with over a dozen regional teacher preparation institutions. BSC has no other graduate programs in physics, due to the close proximity of SUNY University at Buffalo which has a complete offering of physics graduate programs and is the Western New York regional flagship institute for physics research. As a result of the success in these endeavors, the *M.S.Ed. (Physics)* programs and associated activity (the *Summer Physics Teachers' Academy* and the *Western New York Physics Teachers' Alliance*) are viewed with considerable institutional pride, and we consider these as institutionalized.

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Measuring the effectiveness of an inquiry-oriented summer physics course for in-service teachers[1]

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For three consecutive years, we measured the short- and long-term learning gains of in-service middle and high school teachers in an intensive three-week summer physics course for teachers. Significant learning gains were achieved in all course modules and we also found that learning gains achieved in the summer are sustained six to eight months after the end of the course. Our results suggest that courses such as these can be of considerable benefit to teachers irrespective of their level of experience or academic background. The Physics by Inquiry curriculum forms the basis of this course.

Every summer, high school science teachers nationally have the option of enrolling in any one of several physics workshops, courses, and internships. These offerings range from day-long workshops that train teachers in the use of particular equipment lines (PASCO, 2003), to special college-level courses that might last several weeks (University of Washington, 2004; Arizona State University, 2004). Internships are also available that provide summer-long research experiences for teachers in commercial or government research laboratories (NASA 2004; San Diego Science Alliance, 2004). Courses and workshops such as these can be very motivating for teachers. They play an important role in helping teachers keep abreast of advances in the field and innovations in pedagogy, but to what extent do they help those teachers who might have a degree in another discipline and want to improve their understanding of physics? We investigated this question for three consecutive summers in the context of an NSF-funded three-week inquiry-oriented physics (IOP) course at a public liberal arts university in Southern California.

The effectiveness of inquiry-oriented instruction in K-12 science classrooms and at the college level has been has been widely investigated and reported. Hake (1998) compiled data for 6,000 students in introductory physics courses, in which he compared student performance in traditional classes with student performance in classes where an inquiry-based or active engagement mode of instruction was employed. The results clearly demonstrate the effectiveness of inquiry-oriented instruction. Thornton and Sokoloff (1990) show that real-time microcomputer-based tools in a discovery-based laboratory environment can significantly enhance student learning of particular physics concepts. Crouch and Mazur (2001) provide further evidence to support the effectiveness of using active-engagement techniques, after a decade of using a peer tutoring model at Harvard University. Our study is different in that the teachers participating in the IOP course were already science graduates and were teaching science, not necessarily physics, at the high school and middle school level.

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An additional issue for many teachers is the nature of the pedagogy itself. The *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Science Literacy* (AAAS, 1993) stress the importance of inquiry-oriented science teaching. Many local education authorities would like their teachers to adopt this approach and textbook authors support it (Knight, 2004). However, many teachers are still apprehensive about inquiry-oriented instruction and are more comfortable teaching by lecturing, even though they are aware that active learning is a more effective teaching strategy. The IOP course was designed to teach the fundamental concepts of physics in a laboratory-based setting, while at the same time modeling the inquiry-oriented pedagogy. Although we have also investigated the impact of IOP on teachers in their classrooms, we do not report on that here.

The *Physics by Inquiry* Curriculum

McDermott (1990) and McDermott, Shaffer, and Contantinou (2000) stress the need for special courses in the sciences that prepare teachers to teach science using inquiry-oriented instruction. They argue that neither mainstream physics courses nor science methods courses provide adequate preparation for physics and physical science teachers. IOP is a teacher professional development college-level physics course based on the *Physics by Inquiry* curriculum (McDermott, 1996). This curriculum is inquiry-oriented and laboratory-based. Reddish and Steinberg (1999) discuss the value of research-based curriculum, of which *Physics by Inquiry* is an example. *Physics by Inquiry* is founded upon research in physics education and is aligned with a constructivist view of cognitive development. It recognizes that students with minimal background in physics rely heavily on intuition and everyday experience to formulate their views of the physical world (Halloun & Hestenes, 1985; Hammer, 1994). These beliefs do not necessarily translate to an accurate model in terms of the accepted scientific views. In terms of learning theory, new interpretations or restructuring of previously developed schemata must not only have an experiential, but also a reflective component. The *Physics by Inquiry* curriculum was specifically designed to provide both of these components

(Rosenquist & McDermott, 1987), with an emphasis placed on covering certain topics in depth rather than giving a broad overview of physics.

Throughout *Physics by Inquiry*, students are encouraged to construct knowledge for themselves through a process of guided inquiry. Students work with relatively simple equipment to make their own observations, the emphasis being on the process of doing science, and developing critical thinking and scientific reasoning skills. Students record their predictions, observations, measurements, and what they have learned in their laboratory notebooks. They are guided in this process through sequences of carefully formulated questions, and checkpoints with the instructor. Through this approach, students build their own understanding of the concepts being taught. For example, the electric circuits module begins with an activity in which students explore the concept of a "circuit." They do this by connecting a flashlight bulb, a single wire, and a 1.5 volt battery in as many ways as possible to see which configurations light the bulb, and which apparently plausible ones do not. They carefully record sketches of the arrangements they tried and the outcome in each case. They are then asked to identify those characteristics which are common to the configurations that light the bulb. This leads to the development of the concept of a circuit in terms of an operational definition. As the module progresses to more complicated circuits with several bulbs in series and bulbs in parallel, students extend and modify their concept of an electric circuit to accommodate their new observations and data.

The role of the instructors in the course is to augment the guided inquiry embedded in the curriculum by facilitating the students' investigations through the interjection of additional, often more probing, questions. At key checkpoints in the curriculum, the instructors review with the students, through careful questioning, what they have done and what they have learned. The instructors not only facilitate the activities, but also, through their style of interaction with the students, model the inquiry-based learning pedagogy.

A significant strength of the *Physics by Inquiry* curriculum is that it is within reach of almost any teacher in the grade levels targeted in the IOP course. The equipment is simple and inexpensive, and many of the activities can easily be adapted for classroom use. A resourceful teacher could assemble the necessary hardware for very little cost. While the *Physics by Inquiry* curriculum has been shown to be effective in improving undergraduate student understanding of introductory physics concepts (Thacker et al., 1994; Scherr, 2003), its effectiveness in summer physics courses for in-service teachers has not previously been reported.

The IOP Course

There are no formal lectures in the IOP course. It is a hands-on laboratory-based course in which the inquiry-oriented pedagogy is embedded in the style of interaction between the instructors and the participants. The primary goal of the course is to deepen the physics knowledge of science teachers so that they become more confident and excited about teaching physics and physical science. As a teacher's confidence level about a topic increases, they are more likely to engage their students in critical thinking, and provide hands-on inquiry-based science activities.

In the three years of this study, the IOP class met six hours per day, five days per week for three weeks, 45 hours being devoted to each of two topics per year as shown in Table I. The topics were chosen on the basis of their relevance to high school physics teachers. The class met in two sections of approximately sixteen participants each. A faculty member and a trained peer instructor generally taught each section, resulting in a participant-instructor ratio of approximately 12:1. The course was set up as a regular physics course for undergraduate credit and included homework and exams.

Year	Topic I	Topic II
1	Kinematics	Heat & Temperature
2	Electric Circuits	Light & Optics
3	Electrostatics	Magnetism

Table I. *Topics covered in the IOP course.*

An average of thirty-three teachers enrolled in the IOP course each year. Some teachers returned from one year to the next, so that approximately 80 different teachers were involved during the three years. The course was directed primarily at high school teachers teaching grades nine through twelve, but a few carefully selected middle school teachers were included each year. Middle school teachers comprised approximately 20% of the annual enrollment. The majority of the teachers who participated in the IOP course had a degree in a discipline other than physics. However, on average, close to 60% of the participants each year reported that they were teaching physics and over 80% were teaching physical science. Of the 54% of IOP participants who were teaching biology, most were also teaching physical science or general physics. Approximately 10% of the teachers each year were teaching neither physics nor physical science at the time but anticipated such an assignment in the near future.

It was in this context that we investigated the short- and long-term impact of the IOP course on teachers' conceptual knowledge of basic physics. To some extent, the issue of whether a teacher's background is a factor in how much they benefited from the course was also addressed.

Investigating conceptual learning gains in IOP

Conceptual learning gains are difficult to measure objectively, and comparisons from one student to the next are not simple. If a diagnostic pretest is used, a student with a low score on the pretest can potentially attain a larger absolute gain by scoring well on a posttest, relative to the student who scores well on both the pretest and the posttest. This should not be interpreted to mean that the student who did well on the pretest did not gain anything from taking the course. This problem is commonly addressed by using a normalized learning gain to take account of the distribution of pretest scores (Hake, R.R., 1998). The normalized learning gain (*g*) is usually calculated as the difference between the average post- and average pre-test scores divided by the maximum possible score minus the average pretest score:

$$g = \frac{\text{average posttest score - average pretest score}}{\text{maximum possible score - average pretest score}}$$

Learning gains in the IOP course were measured by means of conceptual tests with questions designed to probe understanding, as opposed to quantitative tests in which there is an emphasis on computing "the correct answer." For example, in the Kinematics module, a large emphasis is placed on graphing motion and students' understanding is directly related to their ability to interpret graphs of position, velocity, and acceleration versus time. To test participants' understanding of motion graphs, the published Conceptual Test for the Understanding of Graphs (CTUG) was used as the pre/post test (Beichner, 1994). In cases where standardized conceptual tests were not available, suitable multiple-choice tests were developed to align closely with the concepts presented in *Physics by Inquiry*. Wherever possible, these tests included research-based questions that have been discussed in the literature. For example, the test on Electric Circuits included the well-known question about light bulbs in series and parallel, which asks students to rank the brightness of the bulbs (Shaffer, P. S. and McDermott, L. C., 1992). This test was different from the other tests in that students wrote their answers in free response form, and for some questions, drew circuit diagrams. In the case of the Electrostatics module and the Magnetism module, we used some questions from the Conceptual Survey in Electricity and Magnetism (Hieggelke, 2001) and added questions of our own. Although some of the tests were not standardized, the questions used were research-based and collectively measured the participants' knowledge of the concepts being taught in the course.

At the start of the course each year, participants were given two pretests, one for each module. The graded pretests were not returned to the participants nor were the answers to the questions provided. At the end of the course, the same test was given as part of the final exam. A normalized learning gain was computed for each student for each module.

Each year, one module was selected for the longer-term study. Participants were asked to take the diagnostic test for that module a third time, six to eight months after the end of the course. For these tests, we computed a long-term normalized learning gain relative to the original pretest score. Participants were not aware during the course that this follow-up test would be given. The follow-up tests were mailed to participants and they were asked to complete them without reference to their course notes or physics books. Although there is no way of checking on their honesty with this process, we have no reason to believe that the participants did not follow our instructions in this regard. In the first year, we used the Heat & Temperature test for the long-term follow-up because we were engaged in another study of undergraduate students' understanding of this topic (Jasien and Oberem, 2002). In the second year, the Electric Circuits test was used, and in the last year, the Electrostatics test was chosen for this part of the study.

Learning Gains in the three-week summer course

The graphs in Figures 1 through 6 (see page 20) show the number of teachers scoring at a particular level on the pre- and post-test for each module. Since the questions on the pre-/posttests are intended to probe specific items of conceptual knowledge, an individual's score can be regarded as a measure of that person's conceptual understanding. On the pretests (unshaded bars), between 40 percent and 67 percent of the participants scored less than 50%. This number decreased considerably on the posttests, a trend that is qualitatively evident in all the graphs. For every module, the posttest results (shaded bars) are shifted dramatically to the right relative to the pretest results (unshaded bars), indicating an increase in conceptual understanding. We interpret these data to mean that the conceptual understanding of individual participants has improved considerably by the end of the three-week course, in every topic presented.

Topic	N	Gain
Heat & Temperature	30	0.41
Kinematics	30	0.42
Electric Circuits	36	0.74
Light & Optics	36	0.49
Electrostatics	33	0.40
Magnetism	33	0.38

Table II. *Short-term learning gains by module topic.*

This interpretation is supported by the data in Table II, which shows the short-term learning gains for each of the modules taught in the IOP course. The increases in average scores for all the topics are significant at the 99% confidence level from a paired samples t-test. By way of comparison, in the case of the FCI, learning gains of 0.40 and above have typically been observed for highly interactive courses that promote student engagement (Hake, R.R., 1998). In the IOP course several different topics were taught, not only introductory mechanics, and a variety of diagnostic tests were used. However, the gains measured in IOP were at or above the expected range for an inquiry-oriented mechanics course, as measured by the FCI.

The normalized learning gain for the Electric Circuits module was much higher than for the other modules but, as described earlier, that test had a different format that included several free

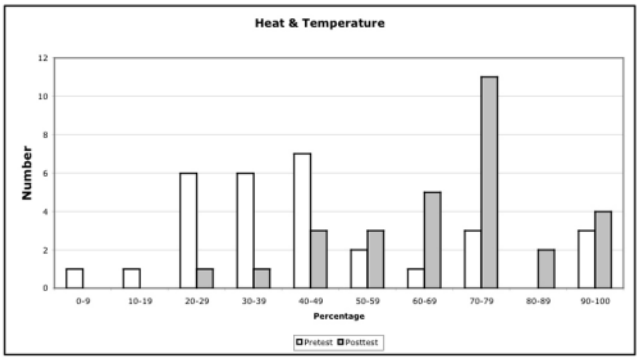

Figure 1. *Graph of number of participants scoring at a particular level on the Heat & Temperature pre- and post-tests.*

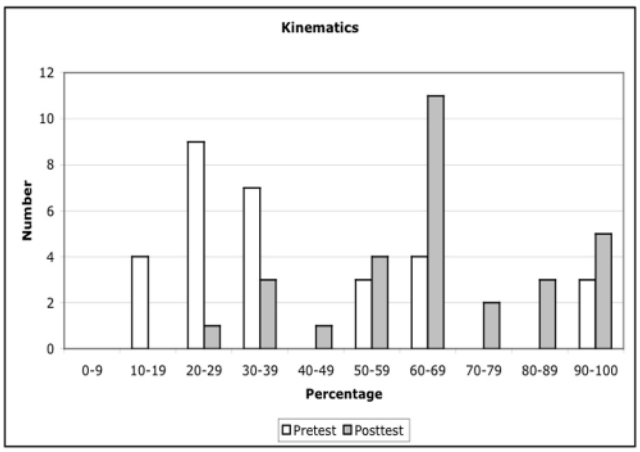

Figure 2. *Graph of number of participants scoring at a particular level on the Kinematics pre- and post-tests.*

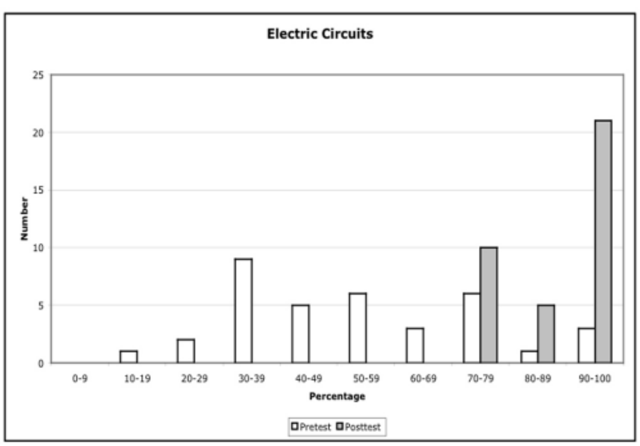

Figure 3. *Graph of number of participants scoring at a particular level on the Electric Circuits pre- and post-tests.*

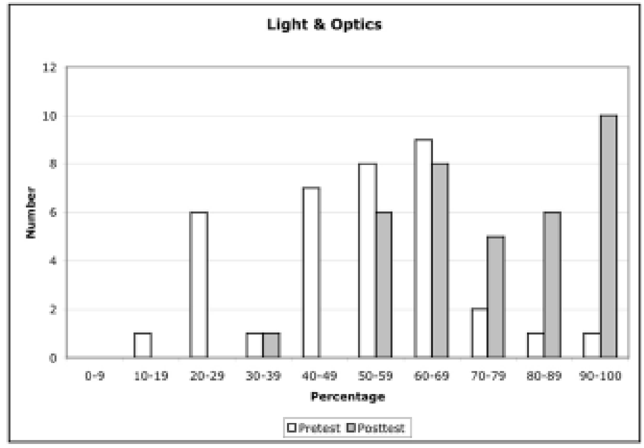

Figure 4. *Graph of number of participants scoring at a particular level on the Light & Optics pre- and post-tests.*

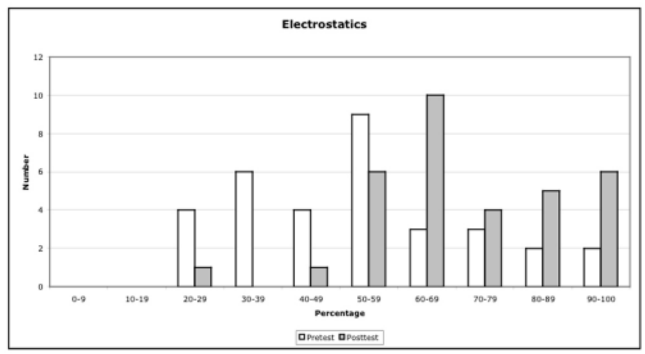

Figure 5. *Graph of number of participants scoring at a particular level on the Electrostatics pre- and post-tests.*

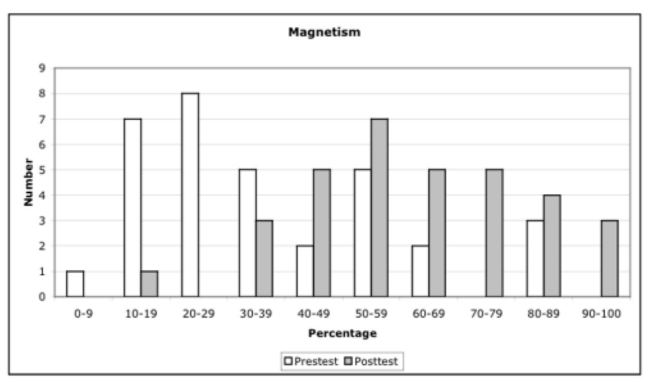

Figure 6. *Graph of number of participants scoring at a particular level on the Magnetism pre- and post-tests.*

response questions and student-drawn circuit diagrams. This was the only test in which students were given partial credit for their responses to particular questions. That could have been a factor in producing a higher overall learning gain in this case.

Do the learning gains persist?

Approximately two thirds of the teachers each year participated in the long-term study. Table III compares the average normalized learning gains at the end of the three-week summer course with the measured learning gains six to eight months later for those teachers who participated in the long-term study.

Topic	N	Gain - Short	Gain - Long
Heat & Temperature	18	0.38	0.41
Electric Circuits	24	0.73	0.63
Electrostatics	22	0.45	0.26

Table III. *Comparison of short- and long-term average learning gains.*

For the Heat & Temperature module and the Electric Circuits module, there is no statistical difference between the short-term and long-term learning gains when using a paired samples t-test to compare average posttest and long-term scores. P-values of 0.78 and 0.11 were obtained for the Heat & Temperature and the Electric Circuits modules respectively. For the Electrostatics module, the p-value was 0.01 indicating that the observed difference is significant. Overall, these are encouraging results as they suggest that the teachers retain much of what they have learned in these modules, even long after the end of the course. In the case of the Electrostatics module, the long-term learning gain is significantly lower than the end of course learning gain. We can only speculate as to why this might be the case. One possibility could be that teachers returning to their classrooms are more likely to teach material relating to heat and temperature or electric circuits, but much less likely to teach electrostatics concepts. Nevertheless, there is still a long-term conceptual gain in electrostatics relative to the start of the summer course, demonstrating that some electrostatics concepts learned in the summer are remembered correctly six to eight months later.

Our findings are consistent with those of Francis et al. (1998), who undertook a longitudinal study of an introductory physics course that used an active-engagement curriculum similar to *Physics by Inquiry*. Francis et al. reported that student learning gains did not decrease significantly as many as four years after the original course.

Teacher background and experience

In IOP, just over 40% of participants had less than five years teaching experience, and we were able to investigate further whether or not this was a factor in a teacher's performance in our course. For this part of the study, participants were grouped according to the number of years they had been teaching. The average pretest score, the average posttest score, and the normalized learning gain were computed for teachers who had less than five years teaching experience. These scores were compared with the same quantities for those teachers who had five or more years of teaching experience. The results are shown in Table IV. A t-test was used to compare the group with more than five years teaching experience with the less experienced group. The p-values calculated demonstrate that there is no significant difference in the average pretest scores, posttest scores, or learning gains for these two groups. Although the more experienced teachers appear to have scored better on these topics, the differences in the scores are not statistically different. This demonstrates that both experienced and novice teachers can benefit from courses like IOP.

Our ability to investigate other factors affecting learning gains in IOP has been limited by the need to split the participants into groups related to the variables of interest. In most cases, the

Topic	N (<5 yrs.) N (5+ yrs.)	Ave. Pre-%	p-value	Ave. Post-%	p-value	Ave. Gain	p-value
Heat & Temperature	14 16	41 41	0.92	68 62	0.41	0.46 0.36	0.76
Kinematics	14 16	42 39	0.71	68 65	0.71	0.45 0.43	0.66
Electric Circuits	13 22	50 56	0.38	88 89	0.69	0.76 0.75	0.80
Light & Optics	13 22	46 54	0.21	72 77	0.47	0.48 0.50	0.57
Electrostatics	17 16	47 57	0.14	66 76	0.08	0.36 0.44	0.29
Magnetism	17 16	34 40	0.44	57 66	0.26	0.35 0.43	0.16

Table IV. *Comparison of performance in relation to experience.*

groups were too small to allow a meaningful statistical analysis. One such issue, of particular interest to us, was whether a participant's academic background was a factor in how much he/she benefited from IOP. Many of the teachers who participated in IOP were not qualified as physics teachers. They were trained in and were currently teaching biology, chemistry, earth science, mathematics, and other disciplines. Grouping participants according to their academic disciples resulted in groups that were too small to allow a rigorous statistical analysis. However, our preliminary results suggest the learning gains of the participants and their level of mastery attained in the course are independent of their academic field of training.

Preliminary results also indicate that the middle school teachers seem to benefit as much as from IOP as do the high school teachers. Although a formal statistical analysis of their performance relative to that of the high school teachers was precluded by their relatively small numbers, it appears that their average posttest scores and learning gains are not significantly different from those of their high school colleagues. Lastly, it is worth noting that the middle school teachers were enthusiastic participants in IOP and one became a valuable peer instructor in the course.

Implications for in-service physics teacher courses

The study described here centered on measuring the effectiveness of using the *Physics by Inquiry* curriculum in the context of the summer IOP course. Our results suggest that an inquiry-oriented in-service physics course can be instrumental in bringing about substantial and sustainable conceptual learning gains for teachers. We believe that the inquiry-oriented nature of the curriculum and the way it was used in our course played a key role in the outcomes we measured, a factor that has been confirmed in other studies. For example, Scherr (2003) attributes her success with using *Physics by Inquiry* in a large class in part to her thorough knowledge of the curriculum and its application. Curriculum developers stress that the proper implementation of curriculum such as this is critical (McDemott, et al., 2000) and offer faculty workshops to provide the necessary background and training.

In summary, the results of this study suggest that inquiry-oriented in-service summer workshops for teachers can be very effective in improving conceptual understanding in physics. It is possible to achieve significant learning gains that persist long after the end of the course, but the success of such courses for teachers is dependent on the curriculum used and its proper implementation.

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Repairing the Illinois high school physics teacher pipeline: Recruitment, preparation and retention of high school physics teachers ~ The Illinois model[1]

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The Illinois Section of the American Association of Physics Teachers (ISAAPT) held a two-day special session during the autumn of 2004 aimed at repairing the Illinois high school physics teacher pipeline. An ad hoc committee was established by the ISAAPT at its Spring 2004 Section meeting for the purpose of reviewing and making recommendations in light of physics teacher shortages being experienced in the State of Illinois. The committee was charged with examining recruitment, preparation, and retention practices for physics teachers in Illinois, and making recommendations for improvement in identified problem areas.

A special research review and discussion session was held by the ISAAPT Ad Hoc Committee on High School Physics Teacher Recruitment, Preparation, and Retention at Illinois Central College in East Peoria, Illinois, on October 14/15, 2004. The purpose of this special session was to address the ongoing and increasingly dire problem with the undersupply of secondary-level physics teachers in the State of Illinois. Recruitment, preparation, and retention of high school physics teachers were the main foci of study and discussion in this session. The work of the Committee resulted in a series of key findings and recommendations that, if followed, will lead to a partial resolution of the identified problems. This Committee presented tentative findings and recommendations at the ISAAPT autumn meeting held on October 16, 2004 at Bradley University in Peoria, IL. This Full Report provides a formal summary of key findings and recommendations, and culminates in "The Illinois Model" for improving the recruitment, preparation, and retention of high school physics teachers.

Repairing the Pipeline

The complete repair of any problem requires a systematic analysis of the problem and a methodical approach to its solution. In order to affect a long-term solution to a problem, pains must be taken to identify and then address the root cause. Cosmetic solutions to any problem are at best temporary. In order to solve the problem of too few qualified physics teachers for Illinois, several important steps are required. First, there must be widespread recognition that the problem exists. The problem *is* pronounced, but it is recognized mainly by those who are directly impacted by the deficit. High school administrators often search in vain for physics teachers. They will of necessity sometimes staff an unfilled physics teaching position with an underqualified or even unqualified teacher. University and community college faculty are often oblivious to the demand for secondary-level physics teachers as they often labor with an adequate supply of "regular" physics and engineering majors. Physics teacher educators are more often aware of the problem; many physics teacher education programs will only graduate one or two certified physics teachers every few years. The cause for an inadequate number of physics teachers and teacher candidates is not so clear to many physics teacher educators and physicists. The doors of university-level teacher education programs are open, but teacher candidates aren't showing up in the numbers required.

It is the belief of this Committee that there is sufficient evidence to document the physics teacher shortage problem, sufficient means by which to identify the source of the problem, and adequate resources to affect a long-term solution to this very serious problem. The Committee is not so naive as to think, however, that it can resolve the shortage problem entirely. There are many factors that affect physics teacher recruitment, preparation, and retention over which stakeholders have little or no control. Nonetheless, this has not stopped the Committee from doing its best to identify those areas where it is possible to make at least some difference. In the subsequent paragraphs of this Full Report, the Committee will review the results of research, provide an analysis of available data, and make recommendations for prioritized actions that might help to reduce the physics teacher shortage problem across the nation, but especially in the State of Illinois.

Physics Teachers: A Growing National Demand

The U.S. Department of Education (2002) predicts that the nation will need more than one million new teachers by the year

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2010. Nearly half of the 2.6 million teachers currently employed in America's schools will leave teaching during the next few years due to a variety of reasons – primarily career changes and retirement. On a national basis, more than one-fourth of all current teachers are over 50 years of age and many are approaching retirement (NCES, 2004).

On a national basis, the attrition rate of new teachers is approximately 10% to 50% in the first three to five years of teaching, depending primarily on the adequacy of teacher preparation (Fuller, SBEC, 2002). Nonetheless, there is NOT currently a general shortage of qualified teachers in the U.S. According to Linda Darling-Hammond (2001), "We face shortages of people willing to work at the salaries and under the working conditions offered in specific locations – in *rural* and *urban* areas." Teacher shortages do exist on a national basis in certain areas such as special education, mathematics, physics, chemistry and Spanish. Teacher shortage – especially in math and science – results in large part from competition for employment. In the disciplines of science and mathematics employers seek knowledge and skills possessed by teacher education majors (AAEE, 2003). There is an adequate supply of prepared and certified teachers in most other areas of education.

The supply problem of physics teachers is made worse by the fact that more and more high school students are taking courses in physics. According to the American Institute of Physics' Statistics Research Center (Neuschatz & McFarling, 2001), enrollments in high school physics are up across the board, and we are now at an all-time high. Since 1986 there has been a steady increase in the number of students taking physics on a national basis. In 1986 only about 17% of all high school students took physics by the time they had graduated. By 2001 the percentage had almost doubled. Girls and minorities are making up a growing percentage of total enrollments in high school physics. More and more students are taking conceptually-oriented physics courses, and the Physics First movement is undoubtedly having an impact on enrollments in some areas of the country.

While many physics courses are being taught by qualified physics teachers, many are the number that are being taught by less qualified, and sometimes unqualified physics teachers. On a national level, only 61% of public high school physics teachers are endorsed to teach physics; only 27% of private/parochial physics teachers are endorsed to teach physics. Only about one-third of all physics teachers majored in physics or physics education (Neuschatz & McFarling, 2001) meaning that the remainder of the high school physics courses probably are being taught by chemistry teachers or by nonphysical science teachers who are teaching entirely out of field. More than 50% of all high school physics teachers are teaching entirely out of field, without a major or minor in physics. It is not at all uncommon to see one-person science departments in rural schools. These teachers are more often than not Biology teachers with little or no formal preparation in physics. A more detailed analysis of the current national situation with regard to high school physics teaching is provided by MacIsaac et al. (2004).

Science excellence in physics is clearly suffering as a result of physics being taught in some high schools by less than completely qualified teachers. For instance, 82% of our nation's twelfth graders performed below the proficient level on the NAEP 2000 science test (NCES, 2001). This number has actually increased since 1995 when it was 79%. NAEP reviewers complain that the longer students spend in the current school system, the worse they do. Fourth graders rank at second place internationally in science; twelfth graders rank at sixteenth place. While there is no direct link between teaching performance and student success per se, careful teacher preparation and subsequent high quality teaching are very important to overall student success. The under-qualification of crossover physics teachers has a definite negative impact on student performance (Ingersoll, 1999). When poor physics teaching performance occurs, it sometimes results in poor student performance and disinterest in the subject matter. It is yet another reason that we are now facing a general critical physics teacher shortage across the United States with major impacts on college majors and careers related to physics.

Physics Teacher Shortage in Illinois

According to data presented by the Council of Chief State School Officers in their report *State Indicators of Science and Mathematics Education* (CCSSO, 2003), Delaware, Illinois, Missouri, North Carolina, and Texas had the greatest shortages of certified high school science teachers. The shortage of physics teachers in Illinois is chronic and growing worse. Teachers are leaving the profession, moving up to administrative positions, moving over to other districts, and moving out as a result of retirement or career change. In Illinois 31% of all high school physics teachers are age 50 or over (CCSSO, 2003). The enrollment in Illinois high schools is growing and is expected to peak in 2007. The net loss of physics teachers and growth in student enrollment coupled with the national trend of a greater percentage of students taking physics exacerbates the problem of physics teacher supply. These factors, coupled with the fact that teacher education institutions across the State are not graduating enough physics teacher candidates, has led to a very significant shortage of qualified physics teachers. Unfortunately, only 64% of Illinois high school physics teachers are endorsed to teach physics, and that percentage is likely falling. The percentage represents a 32% drop from the 1994 value (CCSSO, 2003). Many school districts reported an inadequacy of qualified physics teachers in 2003. Of 231 of the State's 600+ school districts responding to an Illinois State Board of Education (ISBE) survey of supply and demand, 53% indicated a "severe under supply" of physics teachers and 29% indicated an "under supply." Only 18% of school districts in the sample reported an adequate or above adequate supply (ISBE, 2004). According to projected need for physics teachers by the Illinois State Board of Education, the number of openings for physics teachers in the State of Illinois will grow from 46 in the 04/05 school year to 56 in the 07/08 school year. Teacher education institutions in Illinois that graduate physics teachers will provide only 8-12 new physics teachers based on estimates from a 94/95 survey of physics teacher preparation programs. Physics teacher supply in relation to demand suggests that as much as 3/4 of all physics openings currently are being filled by teachers with majors other than physics.

Underqualified and unqualified teachers in physics is having its affect on Illinois schools as can be seen by the results of the annual Prairie State Assessment Exam. According to the Illinois State Board of Education, only 51.3% of eleventh graders in Illinois meet or exceed performance standards. Some 38.0% of all eleventh graders fell below performance on the science standard whereas an additional 10.7% fell substantially below acceptable performance standards and received "academic warnings" in science. This level of performance is associated with the claim that these students are "unable to use science knowledge effectively" (ISBE, 2003).

Recent efforts by the Illinois State Board of Education to certify "highly qualified" teachers of science through a new licensure program is being met with growing skepticism. The Certification Board has plans to replace the current endorsement system (physics, chemistry, biology) with a designation system under which all new science education graduates are permitted to teach introductory courses in any area of science – physics, chemistry, biology, environmental science, and earth and space science – regardless of preparation. Passing a test with approximately 67 science core questions and 33 designation area questions is seen by the Certification Board as an appropriate qualifier for teachers to teach all areas of science regardless of their formal preparation. This is viewed by some as an effort to legitimize the use of underqualified crossover teachers to teach disciplines outside of their degree areas – content tests not withstanding.

Key Findings: Illinois Teacher Candidate Recruitment

One of the committee members, in preparation for the Ad Hoc Committee's special session, conducted two pilot surveys with small numbers. One survey was administered to physics teacher education candidates and the other was administered to in-service teachers of physics and/or physical science. The first survey was completed by 24 of 33 declared physics teacher education candidates. The second survey was completed by 23 of the approximately 80 in-service physics teachers contacted. Findings from both pilot surveys paralleled one another in important dimensions. (Detailed data as well as special session PowerPoint presentations may be accessed on the Committee's website at: http://www.phy.ilstu.edu/pipeline/.)

Teacher Candidates: The teacher candidate survey was oriented toward ascertaining from university students what role various factors played in their decisions to become physics teacher education majors. The primary factors influencing the decisions were the following:

- experiences with good physics teachers
- a desire to make a difference in the lives of people
- positive experiences with teaching others
- interest in science in general and physics in particular
- a desire to demonstrate the broad applicability of physics to everyday phenomena.

The recommendations of physics teachers for students to follow in their footsteps had very little influence on career decision. Conversations with school counselors had a slight negative affect.

In-service Teachers: The in-service teacher survey dealt with both direct and indirect teacher candidate recruitment practices, and with factors that would influence a teacher's decision to leave the teaching profession. There were several interesting findings related to the "joys" of teaching:

- ability to make a difference in the lives of students
- working with people in general and students in particular
- watching students rise to the challenges of physics
- love of the subject matter

The greatest challenges to remaining in the teaching profession were identified as follows:

- poor attitudes of students
- student misbehaviors
- lack of support and respect from students, parents, or administrators
- increasing family demands including relocation of spouse
- too much demand on personal time
- approaching retirement age

As far as direct and indirect recruitment activities are concerned, in-service teachers do NOT appear to actively recruit their students to become teachers; at best, it appears that most teachers model appropriate teaching practices in the hope (or expectation, it's not clear) that students will self-select careers in the teaching of science. *The fact that physics teachers RARELY ask their students to consider careers in physics teaching appears to explain why it is that so many teacher candidates fail to mention that physics teachers had very little direct influence on their decision to become high school physics teachers.* Survey results also show that physics teachers do not consciously involve their prospective teacher candidates in teaching activities or situations that are important to their decisions to become physics teachers.

The parallels between teacher candidates and in-service teachers are striking. Both groups have several important characteristics in common: a strong sense of altruism, a desire to make a difference, a perception that teaching is a pleasurable experience, and a fascination with science in general and physics in particular.

Key Findings: Teacher Candidate Preparation

The Committee members know very little about physics teacher preparation programs statewide in Illinois. From a 1995 survey completed by 8 of 22 physics teacher education program directors, it was clear that most of these institutions are not strongly engaged in teacher preparation. Based on projections, the mean graduation rate for PTE majors was only 0.69 students per institution per year. Fully one half of the institutions surveyed had no students in the physics teaching major. Several had not graduated a physics teacher education major in more than ten years. At least one program has expanded dramatically over the past ten years with more than 30 officially declared physics teaching majors in the physics-teaching pipeline. From the experiences of the Committee members it appears that the vast majority of new physics teacher graduates are from three or four institutions of higher learning within Illinois.

Currently there are 28 institutions of higher learning accredited to graduate and certify physics teacher education majors (ISBE, 2004). With recent more stringent program accreditation changes required by the Illinois State Board of Education, however, there is a possibility that a number of these institutions have effectively dropped out of the physics teacher preparation process. All science teacher preparation programs in Illinois are now required to meet NCATE and NSTA program accreditation standards (NCATE, 2003; NSTA, 2003). The accreditation process and subsequent documentation of teacher candidate performance has become a daunting task. Teacher education institutions with physics education programs in most cases do not have adequate personnel – or students – to justify the expense associated with ongoing program accreditation. Several chairpersons of different teacher preparation institutions have contacted at least one of the Committee members about dropping out of the certification process altogether. Whether or not they have done so is uncertain. Clearly, more information about all phases of teacher preparation in Illinois is desperately needed.

The United States Department of Education (2002) is strongly promoting the alternative certification initiative by way of working to lower barriers that keep qualified candidates out of the teaching field. The State of Illinois is responding. As a result, alternative certification is having a small but growing impact in Illinois. Alternative certification programs are beginning to spring up across Illinois in an effort to satisfy some of the growing demand for new science teachers. Currently there are 14 post-secondary institutions with alternative certifications programs. The typical number of teacher candidates in each of these programs is probably between 10 and 15. They span a number of different fields, but it is not at all unusual to see some of these programs use the cohort model with all candidates from a specific subject area. These are market-driven programs designed to meet the need for teachers in specific school districts such as the Chicago Public Schools. Programs of study are tailor-made to meet the needs of both school districts and teacher candidates who must have at least a Bachelor's degree and several years of work experience in their designated fields. Some of these programs are job-specific in that they recruit teacher candidates to fill specific types of job positions (e.g., science), are field-based with one year of classroom teaching experience, and mentored by in-school and university supervisors. Illinois State University is taking a leading role in this area. Last year they placed four alternative certification science teacher candidates in Illinois high school science classrooms. This coming year (2005) that number is expected to be approximately twenty. "Teach for America" is also beginning to make some inroads on college campuses within Illinois, but the success rate of this program is as of yet uncertain.

The American Physical Society (APS), in cooperation with the American Association of Physics Teachers (AAPT) and the American Institute of Physics (AIP), has initiated a program called the Physics Teacher Education Coalition (PhysTEC) for the purpose of improving the preparation of future K-12 science teachers. The stated goals of this program (PhysTEC, 2001) are to:

- produce more and better-prepared science teachers who are committed to student-centered, inquiry-based, hands-on teaching, as specified in the National Science Education Standards (NRC) and the Benchmarks of Project 2061 (AAAS),
- produce collaboration between physics and education departments,
- create and maintain mentoring and induction programs for PhysTEC graduates, and
- inform the physics and education communities of PhysTEC project outcomes through conferences and publications of the APS, AAPT, and AIP.

The PhysTEC leadership expects, among other things, to improve the quality of physics teacher candidate preparation with an eye toward increasing enrollments in entitlement programs leading to physics teacher certification.

While some might be skeptical of this approach, one such model exists that shows its effectiveness. Illinois State University, which is a member of PhysTEC, has one of the most innovative and successful physics teacher education program in the nation (Wenning, 2001). (See also http://www.phy.ilstu.edu/.) Starting with two pedagogical courses in 1994 and three physics teaching majors, the program has ballooned to include six such courses and the number of declared physics teacher education majors in the spring of 2005 is expected to approach 40. This program provides some evidence for the belief that there is something to the statement from the movie *Field of Dreams,* "Build it and they will come." Illinois State University's physics teacher education program was predicated on this belief, and the State will be rewarded with a growing number of physics teacher education graduates in the coming years.

Based on the described research and the knowledge of some of the Committee members as teacher educators, it seems clear that many PTE programs within the State of Illinois are languishing. This is probably the result of several factors: (1)

many programs do NOT have adequate faculty or staff designated to properly provide a high-quality accredited program, (2) some programs are at best inadequate to the needs of the physics teacher candidates, and (3) inadequate programs are not attracting the teacher candidates necessary to maintain them. Part of the problem can be addressed by giving physics teacher educators credit for activities associated with teacher candidate preparation and service to the public school community, and for professional development.

Key Findings: In-service Teacher Retention

From the survey conducted among in-service high school physics teachers there appears to be a number of trends in teacher attrition. Despite a small sample size and a small return rate (~25%) from a self-selected group could lead to the conclusion that the data are inadequate or biased, identified Illinois trends are closely paralleled by two scientific surveys of a large group of in-service teachers in Texas (Marshall & Marshall, 2003; Moses, Brown, & Tackett, 1999). The identified reasons for actual or potential teacher attrition in Illinois are sorted here into two different categories – those over which external agents have little control and can make little direct difference, and those over which there can be some form of effective external influence:

<u>Lower control</u> – the factors over which external agents have no control:

- poor attitudes of students
- student misbehavior
- lack or support and respect from students, parents, and administrators
- increasing family demands
- relocation of spouse
- unrealistic demands placed on science teachers
- retirement

<u>Higher control</u> – the factors over which external agents might have some influence:

- personal sense of professional inadequacy
- teacher boredom with subject matter
- lack of appropriate mentoring
- inadequate professional preparation

Grave concern was expressed about retention by several of the Committee members for crossover teachers, especially those in urban and rural settings. These teachers often work in solitude, and not infrequently in small schools serve as the "department of science" – teaching a wide variety of disciplines often without appropriate preparation, curricular and instructional materials, and demonstration and laboratory equipment. These teachers are prime candidates for departure from the field of physics teaching. Unfortunately, many if not most isolated high school physics teachers know nothing about the existence of the ISAAPT. One committee member with more than 30 years of high school physics teaching experience had never heard about this organization and believes that that experience is common among many if not most secondary-level physics teachers in rural settings.

Recommendations: Teacher Candidate Recruitment

Of some concern in this area is the response rate to the in-service teacher survey. About 25% of the 80 so teachers contacted responded to the survey. There are, as a result, some concerns regarding the response rate. Is the low response rate indicative of a lack of teacher interest in recruitment? Is the small response rate suggestive of a sense of powerlessness to impact student choice of teaching as a career option? Regardless of these concerns, the Committee makes a number of recommendations based on the survey results from both in-service physics teachers and physics teacher candidates.

<u>The Committee recommends</u> that in-service teachers of physics and physical science should be encouraged to:

- continue to *indirectly* recruit students through excellent science teaching
- *directly* recruit their students to careers in science teaching using a low-key approach
- talk with all students about the need for science teachers
- appeal to the altruism of students
- talk about the joys of teaching
- talk about teaching as a profession
- emphasize the day-to-day applicability of physics
- get students involved in a wide variety of teaching experiences
- involve students in out-of-class science activities
- conduct science outreach activities such as interclass and interschool competitions
- host a peer-oriented science club, science fair, physics day, science olympiad
- conduct science outreach activities for younger children

<u>The Committee recommends</u> these actions of ALL science teachers at ALL levels – elementary school through university level. Many people who select specific careers as doctors, lawyers, scientists, and teachers are found to first have given thought to these and similar professional careers in early childhood. Elementary school teachers, therefore, should think in terms of planting "seeds" with respect to careers in science teaching in the hope that these seeds will be nurtured and then harvested by high school science teachers as well as community college and university faculty. In addition, attitude changes are required among science teachers at all levels. We should discourage the attitude that says "excellent students are too good for teaching" and should encourage teaching as a worthy goal for even the very best of students. Attitudes should be changed from "Those who can, do; those who can't, teach!" to "Those who can, teach!"

In light of the fact that physics (and possibly other science) teacher recruitment is being broadly ignored, the Committee recommends that a generic guide booklet for science teacher recruitment be prepared on the basis of the finding of this report, and disseminated to science teachers statewide. The guidebook should deal with both long- and short-term recruitment efforts for science teachers at all levels. The guide should be prepared and distributed through such networks as ISAAPT, ISTA, IACT, and ICBT. Failing that, a more targeted recruitment guidebook should be prepared to directly address the recruitment of physics and physical science teacher candidates and disseminated directly through the ISAAPT. The Committee recommends further that the ISAAPT should take the lead in producing this publication and then work with science teacher associations statewide, and even nationally, on its dissemination. The Committee recommends also that a website be established for prospective science teacher candidates that provides students with career planning resources.

The question naturally arises about which students to recruit. Not every physics student will make a viable physics teacher candidate. Successful teachers are often successful students that exhibit certain personality traits. Research suggests that selectivity plays an important role on teacher success and student achievement, especially at the secondary level (Rice, 2003). Prospective candidates for recruitment should, therefore, be selected on the basis of personal abilities and attributes most consistent with those of a good science teacher. The abilities extend to scholarship, leadership, and character. The Committee recommends that the following types of students should be *directly* recruited for careers in science teaching if they exhibit a preponderance of the following traits or have the potential for developing them:

- altruistic personality
- self-confidence, self-awareness and self-control
- good academic ability in science
- high interest in science
- interest in learning via active inquiry
- good "stage presence"
- high degree of internal motivation
- enjoys teaching experiences
- strong work ethic
- strong sense of personal integrity (ethical conduct, honesty)
- extrovert with good "people skills"
- leadership skills
- a helper of peers
- an after school "hanger on"

In short, students to be recruited will express interest in science and demonstrate character traits similar to those promoted in the nationally acclaimed *Character Counts!* school program – trustworthiness, respect, responsibility, a sense of fairness, caring for other, and good citizenship (Character Counts!, 2004).

The Committee recommends that the pilot survey of physics teacher candidates be expanded to include all students enrolled in PTE programs across the State of Illinois.

Recommendations: Teacher Candidate Preparation

This is without a doubt the most difficult area for the Committee to make recommendations. As noted earlier, the Committee has very little information about physics teacher education programs within the State of Illinois. Nonetheless, relevant research suggests that five major factors are important to the preparation of quality teachers. These include the following: teaching experience, preparation programs and degrees, type of certification, specific coursework taken in preparation for teaching, and a teacher's own test scores (Rice, 2003). In light of the fact that several Illinois post-secondary institutions are having good success in recruiting and preparing physics teacher candidates, the Committee recommends that:

- a network of PTE institutions be established so they can share resources needed for physics teacher preparation and program accreditation, and
- an annual survey be conducted of institutions with PTE programs and establish a central repository with information about PTE programs.

In light of the fact that much of the service associated with teacher preparation is not properly credited in the tenure and promotion process at 2-year and 4-year colleges (implying time spent on teacher preparation is of less worth than research), the Committee recommends that an offer of assistance be prepared and disseminated to select physics teacher education faculty at institutions of higher learning across Illinois. The purpose of this offer of assistance would be to promote credit for service in teacher preparation programs as part of the promotion and tenure process.

The Committee recommends that the ISAAPT Executive Council seriously consider becoming more proactive in making recommendations to the State's Certification Board, and more reactive to its many mandates. For instance, it could be argued that the qualifications identified by the ISBE in response to NCLB legislation (United States Department of Education, 2003) are more reflective of a "minimally qualified teacher" than a "highly qualified teacher." Additionally, it could be argued that the ISBE's decision to replace science teacher endorsement areas (physics, chemistry, biology) with a single generic science endorsement is fundamentally flawed.

Recommendations: In-service Teacher Retention

Concerns of Committee members about in-service teacher retention spanned a range from induction and mentoring, to appropriate performance assessment and ongoing professional development. These problems are of particular concern in urban and rural settings where in-service teachers tend to receive little professional support. The Committee recommends that the following efforts be focused primarily on providing assistance to in-service teachers working in urban/rural settings:

- seek to improve in-service physics teacher awareness of the existence of the ISAAPT,
- make ISAAPT meetings more useful to in-service physics teachers by emphasizing throughout the program practical applications of physics knowledge through such things as "Take 5" presentations, Teachers Teaching Teachers workshops, and talks focusing on the teaching of high school physics,
- publish curricular materials in a central Web-based electronic clearinghouse,
- develop an e-mail listserv for curriculum sharing and dissemination of information related to professional development opportunities within the State,
- establish a network consisting of individuals (retired physics teachers?) to provide mentoring to established in-service teachers
- work with ISTA to provide yearly conference-related workshops that provide isolated and crossover physics teachers with a wealth of teaching ideas and simple materials,
- seek and obtain a World Year of Physics 2005 grant to support the above mentioned conference-related workshops,
- consult with IACT about getting more in-service high school physics teachers involved with the ISAAPT, and
- promote the development of physics teacher alliances between community colleges and universities and their surrounding high school physics teachers.

The Committee recommends that the pilot survey of in-service physics teachers be expanded to include as many of the 400+ in-service high school physics teachers across Illinois as possible.

The Illinois Model

With such a dearth of Illinois high school physics teachers, with such a pressing need for their recruitment, preparation, and retention, and with so many corresponding recommendations, the Ad Hoc Committee on High School Physics Teacher Recruitment, Preparation, and Retention has arranged in priority order the most important of recommendations. While recommendations are provided below in rank order, the order is in no way entirely suggestive of importance. All recommendations are important and will play a central role in repairing the Illinois high school physics teacher pipeline. Neither do the following priority listings indicate that one suggestion should be completed before another. Indeed, efforts should be made on all fronts to implement all recommendations as quickly and as completely as possible. The following recommendations are to be given high priority because they promise to have the greatest effect at the least cost of time and effort. The Committee suggests that these recommendations be fully implemented within the first year of adoption by the ISAAPT Executive Council. The Committee further suggests that teacher recruitment, preparation, and retention efforts be integrated with those of other fields in science education.

Teacher Candidate Recruitment: The Committee suggests the following priority actions geared toward repairing the Illinois high school physics teacher pipeline in terms of teacher candidate recruitment:

1. Draft and then work with the ISTA if possible to publish a small recruitment guidebook containing a rationale and detailed guidelines for science teacher candidate recruitment at all levels.
2. Create a mailing database of all high school physics teachers for the purpose of disseminating the above mentioned recruitment guidebook.
3. Work with the ISTA to disseminate the recruitment guidebook to all other areas and levels of science teachers within the State of Illinois.
4. Encourage statewide science teacher associations to become actively involved in science teacher candidate recruitment by whatever means possible.
5. Expand the pilot physics teacher candidate survey to encompass a broader range of students.

Teacher Candidate Preparation: The Committee suggests the following priority actions geared toward repairing the Illinois high school physics teacher pipeline in terms of teacher candidate preparation:

1. Create and conduct a detailed annual survey of PTE institutions, reporting on a yearly basis to the ISAAPT Executive Committee the status of physics teacher candidate preparation in Illinois.
2. Make recommendations to the ISAAPT Executive Council for one or more position statements relative to teacher candidate testing and endorsements that, if adopted, will be shared with peer organizations for ultimate presentation to the ISBE Certification Board.
3. Create a series of recommendations for College and Departmental Faculty Status Committees at post-secondary institutions statewide that provide credit for service in the area of teacher preparation in the tenure and promotion process.

In-service Teacher Retention: The Committee suggests the following priority actions geared toward repairing the Illinois high school physics teacher pipeline in terms of in-service teacher retention:

1. Establish and maintain a physics-based teachers' academy – Teachers Teaching Teachers – at the annual statewide ISTA meeting for the purpose of providing support for isolated urban and rural teachers of physics.
2. Seek and obtain a $1,000 grant as part of the AAPT's World Year of Physics for promoting Teachers Teaching Teachers workshops at the November 2005 ISTA meeting.
3. Regularly host a High School Physics Teaching Symposium at autumn Section meetings similar to the Student Research Symposium at the spring meeting
4. Build ISAAPT's reputation among state physics teachers as "helpful" and increase in-service teacher attendance at all Section meetings.
5. More effectively use the Section's newsletter, *Illinois Physics Teacher,* as an avenue for reaching in-service physics teachers.

Implementing the Committee's Recommendations

A question now arises, "Who should implement these suggestions if they are found to be acceptable?" The answer is that everyone with a stake in having a greater number of authentically qualified physics teachers in Illinois high school classrooms should be the ones to implement these actions as soon as possible and to the greatest extent. This includes but is not limited to in-service high school physics teachers, departmental chairpersons, school administrators, teacher educators, and professional associations such as ISAAPT, ISTA, IACT, and IABT. <u>The Committee recommends</u>, finally, that the ISAAPT president should establish three Standing Committees under the leadership and guidance of the Executive Council and in cooperation with the Chicago Section of the American Association of Physics Teachers. The purpose for which these Standing Committees should be established is to implement the recommendations of the Ad Hoc Committee on Recruitment, Preparation, and Retention. Each of the Standing Committees should focus its efforts on one of the following sets of recommendations: Physics Teacher Candidate Recruitment, Physics Teacher Candidate Preparation, and In-service Physics Teacher Retention with specific tasks and time lines.

Committee Members and Participants

The following individuals participated in the presentations and follow-up discussions that resulted in the above findings and recommendations. Those whose names appear in *italic* were committee members responsible for the implementation of the process.

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