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Physics Teacher Education Program Reform

Over the course of the past few months I've had the pleasure of speaking at length with a number of physics teaching program coordinators. Several have remarked with wonder at the number of online resources assembled for the Physics Teacher Education (PTE) program here at Illinois State University (http://phy.ilstu.edu/pte/). I generally get two sorts of questions in relation to these resources: (1) "As a one-man operation, how did you do it?" and (2) "Where do you find the time and motivation?" Because so many of our company who administer PTE programs might have the same questions, I'll take a bit of my brief summer holiday to provide some answers that might provide some insight.

How did I do it? The answer is a relatively simple, "One page at a time." When I started working with PTE program at Illinois State in July of 1994 I was rather clueless about how to run such a program. While I was a certified high school physics teacher, I knew next to nothing about how to prepare teachers. My own preparation had been a bit "thin." The individual who managed ISU's physics teacher education program previous to me came to my office on the day he retired and handed me 11 sheets of paper. He said something to the effect, "If you have the kids do these 11 readings, and you follow up with the corresponding interviews, that ought to about do it for the PHYSICS 301 physics teaching methods course." Right then and there I knew that there had to more to physics teacher preparation than that. There began my journey building the program that we have today.

When I was quite a bit younger than I am today my mother sagely told me, "If you write even one page per day, you can write a whole 365-page book in a year." I never forgot those words of wisdom, and we might all do well to reflect on them. Over the course of the years I have developed my courses and web resources literally "one page at a time." I have committed serious effort at being a reflective practitioner, and have learned from mistakes over the years. Suffice it to say that I have learned a lot!

I started autumn semester of 1994 with an updated but still rather anemic physics teaching methods course, and a pilot of a new course, PHYSICS 302 - *Computer Applications for High School Physics.* Previous to my involvement in this course, students built a photogate - that's it. We had 2 or 3 majors in the major which was (and remains) typical for such programs.

Since that time I have developed six physics teaching methods courses and one rather “intense” student teaching course. We now have about 45 physics teacher education majors in the department, and a substantial PTE Web site. That web site gets more than 6,000 “hits” each week. In addition, the retention rate of our program graduates is about 90% for those who have been teaching for 5 years or more. Compare this with the national drop out rate of 50% within five years. The percentage is even higher if one includes all graduates this past spring.

The motivation for this work comes from a number of areas, but the most important is having a passion for the work. When I realize that what I do will have an impact on a generation of my own students, and then generations of my students’ students, I can’t help but be excited about what I do. I really do believe that “teachers touch the future” and am willing to give what it takes to do a good job. The only way this project could have been done is with a substantial time commitment. Over the years it has not been unusual to seem me come into campus by 8 a.m. and then not leave until nearly 6 p.m. My days have been filled with unrelenting effort.

Is the resulting program perfect and without flaw? Not at all. I’ve learned over the years that I still have much to learn, and every time I learn something it’s back to the drawing board. This summer, for instance, I received a small DOE grant to help solicit and prepare future generations of physics teachers for the high needs urban school district of Chicago. I spent five days living in the very community I plan to take more than of a dozen of my teacher candidates to during autumn semester as part of my PHYSICS 209 course - *Introduction to Teaching High School Physics.* I then spent several more weeks reading and getting better prepared for the task before me - developing a series of urban clinical experiences. After that, as summer vacation time dwindled away, I found myself working hard at developing travel and placement plans for my Urban Studies Field Trip. I have also improved my PHYSICS 311 course - *Teaching High School Physics* - as result of this work. And so it is with so much of the program development here at ISU. It’s literally one page at a time.

PTE directors are sometimes rather surprised that I encourage them to make use of anything they find worthwhile on my Web pages. I believe that it is better to learn from others’ mistakes than having to experience them on their own. The best way to reform existing physics teacher education programs, therefore, is to pick up where others have left off. Why forge of path of your own when others have gone before you?

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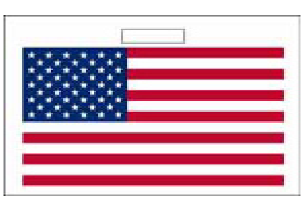

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JPTEO

Guiding experiences in physics instruction for undergraduates

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Although many physics students perform undergraduate research, they are seldom given the chance to develop their instructional skills. This aspect is important because many physics majors entering graduate school might be required to work as laboratory assistants, teaching assistant, or classroom instructors. Those who decide to go into industry or a laboratory setting might be required to prepare professional presentations. This article summarizes the learning experiences of Michelle, a senior physics major enrolled in a unique elective course that made her a physical science lab instructor. This course included teaching pre-lab lectures or post-lab summaries under the supervision of an experienced physics educator and working one-on-one with students throughout the laboratory period as teaching assistant. In addition, Michelle had the opportunity of reading and critically analyzing the basic literature on physics education research.

Introduction

Many undergraduate students in the sciences are exposed to significant research experiences (McIntosh, 2001; Seymour, Hunter, Laursen, and DeAntoni, 2004; Tobochnik, 2001). In a recent survey of physics majors, about 75% of seniors indicated that they had participated in some type of undergraduate research project (Mulvey and Nicholson, 2006).Unfortunately, they rarely have the opportunity to fully develop their instructional and presentation skills (Yellin, Turns, and Getahun, 2005). However, when they enter graduate school, many of them might be required to work as laboratory or teaching assistant. Some might even teach introductory science courses, including laboratory sessions. Other students might go directly into industry or a laboratory setting, where professional presentations might be required.

In these cases, it is assumed that because the student has a solid knowledge of science, he or she can be a good instructor or presenter. To the contrary, research on science instruction suggests that content knowledge alone is a necessary but not sufficient factor in developing teaching proficiency (Anderson and Mitchener, 1994; Doster, Jackson, and Smith; 1997; Shulman, 1997). In addition, students who are required to tutor or teach other students experience a deeper understanding of the subject matter as they reflect on both the content and the best way to explain it to their peers (Harper, May and Oliver, 2002; Miller, Groccia, and Miller, 2001; Nilsson, 2001, Whitman, 1988). Interestingly, those students who are being taught by a peer might feel less intimidated and more willing to ask questions, creating a better learning environment and better academic achievement (Fagen, Crouch, and Mazur, 2002; Goodlad and Hirst, 1989: Libarkin and Mencke, 2002).

A Guided Experience

Our institution has taken a proactive role in providing academically outstanding, junior and senior physics majors the opportunity to begin developing their pedagogical skills in a supervised environment. During the Spring 2006 semester, the course *Special Problems in Physics and Astronomy: Guided Experiences in Physics Instruction* was offered for the first time. The course is described as follows:

> [It] is designed for physics majors to start developing their instructional skills in physics. In close coordination with the regular lab instructor, the student will prepare and teach some of the pre-laboratory lectures and/or the post-lab summaries, in addition of working as laboratory assistant. The student will become familiar with the basic literature in physics education research. Through regular meetings, the student will reflect on the assigned readings and their instructional practice.

The course physics majors are co-teaching with the instructor is *Introduction to Physical Science Laboratory*, a general education requirement for non-science majors.

This *Special Problems* course has three major components: (a) large group instruction, (b) working one-on-one with students throughout the lab period as teaching assistants, and (c) a critical analysis of the basics of physics education research. During the first weeks of class, and before the direct instruction component begins, the physics majors observe the instructor's pre-laboratory lectures and the post-lab summaries. They pay particular attention to the delivery of the material, the use of audiovisuals and demonstrations, and the supplementary explanations in addition to the lab manual instructions. Later in the semester, the physics majors will prepare themselves to teach between 3-5 post-lab summaries, lasting about 5 minutes each. For this part, no audiovisuals other than the white board are required. Eventually, they will prepare to take over between 3-5 pre-laboratory lectures. These will last about 20 minutes and require the utilization of audiovisual materials, such as PowerPoint slides and demonstration equipment. The physics majors do not teach twice during a given lab period. This allows the instructor the opportunity for clarification or extension of the week's topic.

Throughout the semester, physics majors met with the instructor to critically reflect on their performance on the pre-laboratory lectures or the post-lab summaries and to synthesize the lessons learned. Allowing students to verbalize what they learned from their own experience is an essential skill with many long-term benefits (Munby and Russell, 1994) and facilitated many teachable moments. The instructor provided some feedback on strengths and suggests areas of improvement. It is expected that, as the semester progresses, the areas of strength will grow and there will be less areas needing improvement.

The physics majors are also working as laboratory assistants for that section. As such, they visit each table, asking students if they have questions, clarifying procedure steps, and helping with problem solving. The opportunity to interact in smaller groups and one-on-one gives them a different experience and a better understanding of individual learning differences.

A final requirement for the course is to become acquainted with the basics of physics education research. Using *Five Easy Lessons* (Knight, 2004), physics majors write weekly reading reflections. For each chapter, they write a one page, single-spaced report in which the following questions are addressed: (a) what are the most important points of the chapter? and (b) in what ways does your understanding of the topic have changed after reading the chapter? It is expected that students will experience cognitive dissonance (Festiger, 1957) when they compare the way they were taught science and the way it should be taught, as advocated by recent science education reform efforts (National Research Council, 1995).

This *Special Problems* course is an elective at this point. Requiring the course for all physics majors might be considered in the future. However, it is recognized that not all students have the disposition for teaching. Currently, only physics students interested in teaching have shown willingness to take the course.

Michelle, the student who completed the course most recently, decided to keep a journal of her thoughts and progress in the course. The idea was an excellent one, given the fact that reflection through writing has been long recognized by physics educators as an important communication skill (Allie, Buffler, Kaunda, and Inglis, 1997). It is also suggested that the quality of student learning is greatly enhanced through the extra cognitive demands of writing (Prain, Hand, and Kay, 1997). In the next section, and after organizing her journal entries into a humorous yet deeply personal narration, Michelle shares her struggles and satisfactions as the semester progressed.

Michelle's Personal Experience

Every physics major must take a course called "Special Problems". This course involves choosing a professor and collaborating on their research projects for a semester. Unfortunately, I had little interest in any of the research fields offered by any of the professors that I knew of. That changed after a colloquium course a few semesters ago, when I was introduced to physics education research (PER). I thought the professor's presentation was the most interesting of all the presentations throughout that semester. For some reason, this topic struck a cord with me. It might have been that, as a teacher's assistant (TA) for the general physics labs since the beginning of my junior year, several students have told me that I was their favorite TA. Some students would ditch their labs to come to mine because they thought I was very helpful. When I was informed of the new course *Guided Experiences in Physics Instruction* under the tutelage of the same professor, I figured it would be a unique opportunity to explore my area of interest.

Although I had some experience as TA, I knew the responsibility would be more. I would actually be in charge of lecture in addition to answering questions and giving direction. I knew the students I would teach would not be the same as our physics labs. Unlike the general physics lab, which is mostly engineering majors, almost all *Introduction to Physical Science* students were not science majors and did not have the same math background or good understanding of most physical concepts.

I expected to be bad at lecturing at first. I knew I would need a lot of practice and encouragement. In several of my other courses, we had to give end of the semester presentations. I always did badly. It doesn't matter how well I knew the material or how much I practiced, I always seemed to forget everything and freeze up.

The first time that I lectured, it was a post-laboratory summary. The lab instructor gave me pointers the week before and I tried to remember them all. On the positive side, I spoke at a correct volume and tone. However, there were many areas of improvement. I stuttered a few times. Writing on the board was particularly tricky. I wrote on the board with my back facing the class and stood directly in front of what I wrote. Not that it mattered, I wrote so small no one was able to read it had I not been blocking it.

I did prepare to say certain things during the summary that day. In my experience with the general physics lab, many of the quiz questions are not straightforward so the instructors will usually give hints on how to do these problems. Also, when there are problems in the lab manual, the instructor will go over the harder problems. For physical science lab, the problems were straightforward and quite simple. Therefore, the students were expected to know how to solve them. Mostly, I was just supposed to restate what had already been said and summarize everything, which was not what I prepared to say. Since what I had expected to say was tossed out, I got lost and just babbled for ten minutes. This shows the importance of knowing the capabilities of your students and planning the instruction accordingly.

The first few lectures were pretty bad, I think. Each time I would improve something, but it wouldn't be enough to term the lecture "good." One time I became overconfident, didn't prepare as well as I should have, and I gave a terrible lecture. The instructor's post-lab summary had to be twice as long that day to make up for my awful lecture. I learned my lesson. Another time I got sick, so my lecture was not as sharp that day.

One thing I was surprised about was the students' attitude towards me. Most students were not very friendly at the beginning. I would just walk around and ask if anyone needed anything. Most of the time, the students would say, "No thanks, I'm good." Usually they weren't, and they'd wait until the instructor came around to ask him the question. They just weren't comfortable asking for my help. On the few occasions when students would ask me questions, they usually weren't conceptual but procedural, such as: "Which data column should be on the x-axis?" or "How do we use the percent difference equation?"

Later in the semester, students started opening up and asking more conceptual questions. Despite my many physics courses, some of them were surprisingly hard to answer. My experience with engineering majors was different. If they didn't understand it, they would just accept a definition or explanation without asking why. The physical science students were interested in the why behind the physics concepts. Questions like, "Why is the image virtual?" and "Why did the mirror have a focal point behind it?" were both simple and interestingly complicated. If you would have asked me a conceptual question about any introductory physics idea before this semester, I probably would have answered incorrectly.

Over time, my lecturing skills improved greatly. Now, I speak well, I don't stand in front of the board, I summarize using PowerPoint slides while adding more examples and explanation to give the ideas presented more value for the students. Recently I received a fairly nice comment from one of the students. One day after lab, a student who had been a substitute teacher prior to going back to college said: "I enjoy having you in class. You help me a lot…I think you are doing a fine job in all respects." I was so elated after I talked to her I smiled for the rest of the day.

During this semester, I also had to read a book on PER (Knight, 2004). I thought the book was very interesting. At first, I was skeptical. The first few chapters explained, using data from research and case studies, that teaching through lecture is not very efficient and what instructional strategies are more successful. I had not one positive thing to say until chapter 5. I'm a straight-A student who has learned through nothing but lecture. I do not take kindly to these accusations that lecture is bad. However, as you go through the book and think about the experiences you've had in the classroom and classmates that you saw fail over and over; you realize that not all students learn the same way and that a change should be made if we want more students to successfully complete physics courses.

After chapter 5, the book goes over how to teach every physics subject down to what day, actual phrases to use, and worksheets to give the class. The author recommends books to use and what subjects to avoid. He tells you how the class will react to the teaching style and how to keep them learning. Interestingly, the author presents the physics topics in a conceptual way that makes me understand them, which I don't think was the author's objective. He wanted the readers to teach the concepts to the students in the proper way, not to teach the readers the concepts.

I think I'm going to leave this course with a sense of pride in my ability to teach and awareness of where I belong. I would definitely recommend a similar course to anyone who plans on teaching or to attend graduate school. Also, I recommend Knight's book to anyone in the sciences because it is very helpful in the understanding of physics as well as how to teach it. I think I've learned more this semester than the last five semesters combined. Finally, I strongly suggest every undergraduate school to develop a similar course for their students.

Conclusion

It is known that physics seniors who had participated in an undergraduate research experience were three times more likely to plan to immediately continue with physics graduate study than students who had not (Mulvey and Nicholson, 2006). These authors also reported that about 9% of seniors in physics graduating from bachelor granting institutions said they were undecided about their post baccalaureate plans. However, because many departments do not emphasize instructional experiences as strongly as research ones, it is not known how many students might become more interested in teaching after completing an instructional experience, like the elective course developed at our institution. Given the fact that a number of physics graduates develop an interest in a career in education and enter alternative certification programs to become teachers (Zhao, 2005), providing them the chance of "testing the waters" of teaching in a supervised context before they graduate can only increase the pool of qualified teacher candidates, thus helping reduce the shortages reported in the literature (National Education Association, 2007; Richardson and Watt, 2005). Even if these physics majors who completed an instructional experience do not become teachers, the benefit of them reflecting on science concepts and the best way to present them to non-science majors is an important skill by itself.

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Gender differences in physics: A focus on motivation

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In order to better understand the gender differences in motivation that exist in physics, 129 college students from an introductory level calculus-based physics course were surveyed using the Physics Motivation Questionnaire (PMQ). Results indicated that overall, the women had lower motivation that the men. In order to better explore these differences, gender differences in the six components of the PMQ were examined. Results indicated that the women had lower intrinsic motivation, lower self-efficacy, higher assessment anxiety, and were less likely to see the relevancy of the physics they were learning to their personal goals. Implications of these findings for physics instruction at the high school and college level are discussed. Results suggest providing high school and college level women with (1) projects and assignments that connect the physics they are learning to their majors, career goals, and everyday life and (2) mastery experiences in physics, particularly those in the form of enactive hands-on experiences.

The underrepresentation of women in the sciences is a significant and well-documented societal concern (Miller, Blessing, & Schwartz, 2006; Stake, 2006). For instance, in recent years, women received 34% of the Masters degrees in computer science, 21% of the Masters degrees in physics, 41% of the Masters degrees in chemistry, and 21% of the Masters degrees in engineering (National Science Foundation [NSF], 2004). Results for doctoral degrees were similar: Women received 19% of the doctoral degrees in computer science, 13% of the doctoral degrees in physics, 32% of the doctoral degrees in chemistry, and 17% of the doctoral degrees in engineering. Thus women are greatly underrepresented in the sciences, particularly in more advanced degrees and degrees involving physics and engineering.

Gender differences in science achievement on standardized tests from K-12 (e.g. National Assessment of Educational Progress [NAEP], 2005) have been thought to keep females from pursuing advanced courses and careers in science (e.g. Katz, Allbritton, Aronis, Wilson, & Soffa, 2006). When standardized test scores are examined, gender differences in achievement have been reported as early as the fourth grade, and the gap in achievement increases as students progress through school; these gender differences exist on both the life science and physical science sections of achievement tests including the NAEP and the International Assessment of Educational Progress (Beller & Gafni, 1996; NAEP, 2005). The largest differences in achievement, however, exist in the physical sciences, particularly in physics (Beller & Gafni, 1996; NSF, 2004). From elementary school through high school, males have been found to have higher scores on physics sections of achievement tests (e.g. NAEP, 2005).

The bulk of the research on gender differences in all areas of science has focused on motivation as an explanation for women's lower achievement and participation in science, with women showing substantially less motivation to participate in science classes and careers (e.g. Mattern & Schau, 2002), particularly in the area of physics (e.g. Benbow & Minor, 1986). The purpose of this study is to better understand gender differences in motivation in physics by examining the key components that contribute to student motivation in science. The goal is to understand where these specific differences exist in order to better help researchers and instructors minimize the large gender differences in achievement and participation that exist in physics.

Key Components of Motivation

Research indicates that the important components that should be taken into account when examining students' motivation to learn science includes intrinsic motivation, extrinsic motivation, relevancy of task to personal goals, self-determination, self-efficacy, and assessment anxiety (e.g. Glynn & Koballa, 2006). What follows is a brief discussion of these components.

Motivation to perform a task for its own sake is mainly intrinsic, whereas motivation to perform a task as a means to an end is mainly extrinsic (Ryan & Deci, 2000). For instance, students who are intrinsically motivated work on a task because they find it interesting; students who are extrinsically motivated work on a task to attain a desirable outcome such as a good grade. However, both types of motivation are important in contributing to students' success in their science courses (Pintrich & Schunk, 2002).

Another important component of motivation is the relevancy of a task to a student's goals. How important a student finds a task, or values a task, influences how much time he or she spends on a task (Feather, 1988). Self-determination refers to students having some choice and control in their learning (Ryan & Deci, 2000). When science students have the opportunity to choose what their assignments will be, they are more likely to enjoy and benefit from the assignments (Glynn & Koballa, 2005).

Self-efficacy refers to a student's belief that he or she can achieve in a specific area (Bandura 1997). Self-efficacy affects choice of activities, including career choice (Hackett & Betz, 1981). Self-efficacy also influences achievement. Zusho and Pintrich (2003) found that even after controlling for prior achievement, students' self-efficacy was the best predictor of grades in an introductory college chemistry course. Finally, assessment anxiety is an important component of motivation. A high level of assessment anxiety has been found to interfere with a student's performance on a task, and students perform best when their level of anxiety is at a moderate level (e.g. Cassady & Johnson, 2002).

Method

Participants

Four introductory level calculus-based physics courses from three universities in the southeast United States (one large public university, one large private university, and a small public university) participated in the study. Specifically, 129 students (85 men and 44 women) from a total of 181 students (120 men and 61 women) participated in the study. Thus a majority of the students participated (71%), and students who participated earned a small amount of extra credit.

The calculus-based course is a required course for physics and engineering majors, but many students in the course take the class as a requirement for medical school. These students may or may not be science majors, and choose to take the calculus-based course, rather than the trigonometry-based level physics course also offered, in order to be more competitive when applying to medical school.

Physics Motivation Questionnaire

Student motivation in physics was assessed using the Physics Motivation Questionnaire (PMQ) (Glynn & Koballa, 2006), and can be seen in Table 1 on the next page. The PMQ includes 30 items that assess six key components of motivation including intrinsically motivated physics learning (items 1, 16, 22, 27, and 30), extrinsically motivated physics learning (items 3, 7, 10, 15, and 17), relevance of learning physics to personal goals (items 2, 11, 19, 23, and 25), self-determination for learning physics (items 5, 8, 9, 20, and 26), self-efficacy for learning physics (items 12, 21, 24, 28, and 29), and anxiety about physics assessment (items 4, 6, 13, 14, and 18). Students responded to each of the 30 randomly-ordered items on a 5-point Likert scale ranging from 1 (never) to 5 (always) from the perspective of "when learning physics.." The anxiety about physics assessment items were reverse scored when added to the total, so that a higher score on this component meant less anxiety.

Previous findings (Glynn & Koballa, 2006) indicate that the PMQ is reliable as measured by coefficient alpha ($\alpha = .93$), and valid in terms of positive correlations with college students' science grades, decision to major in science, interest in science careers, and number of science courses taken. Interviews with students in previous studies using this scale further support the validity of the PMQ (Glynn, Taasoobshirazi, & Brickman, in press). For this study, internal consistency (Cronbach's alpha) was found to be ($\alpha = .91$)

In order to better understand students' motivation for enrolling in the course, the students were asked to indicate their major. A list of the students' majors can be seen in Table 2. The number of males and females selecting each major is also reported. Students were also asked to write down their reason for taking the course. When reading through students' responses, it was found that students were enrolled in the course for three different reasons: as a requirement for their program of study ($n = 96$) 71 males and 25 females, as a medical school requirement ($n = 30$) 11 males and 19 females, or because they enjoy physics ($n = 3$), 3 males. Thus women, in comparison to men, tended to enroll in the course for a medical school requirement. No women stated that they enrolled in the course because they enjoyed physics.

Results

In order to examine gender differences in motivation, seven independent-samples *t*-tests were conducted. There was a significant difference in the overall motivation ratings of the men ($M = 104.85$, $SD = 15.27$) and women ($M = 92.86$, $SD = 17.43$), $t(127) = 4.03$, $p < .05$, Cohen's $d = .73$, with the men having more motivation in physics than the women.

Major	Number of Students	% of Students	Number of Males	Number of Females
Engineering	44	34.1	39	5
Biology	27	20.9	13	14
Chemistry	16	12.4	9	7
Math	11	8.5	5	6
Physics	9	6.9	7	2
Business	6	4.7	5	1
Computer Science	5	3.9	4	1
Psychology	3	2.3	0	3
Sociology	2	1.6	1	1
Environmental Science	2	1.6	1	1
American Studies	1	.78	0	1
Anthropology	1	.78	0	1
Architecture	1	.78	1	0
Creative Writing	1	.78	0	1

Table 2. *Majors of the Students (n = 129)*

When examining the individual components, there was a significant difference in the intrinsic motivation of the men ($M = 18.11$, $SD = 4.13$) and women ($M = 16.02$, $SD = 4.40$), $t(127) = 2.66$, $p < .05$, Cohen's $d = .49$, with the men having more intrinsic motivation in physics than the women. There was not, however, a significant difference in the extrinsic motivation of the men ($M = 19.00$, $SD = 3.24$) and women ($M = 18.45$, $SD = 3.25$), $t(127) = .91$, $p > .05$, Cohen's $d = .17$.

There was significant difference in the relevancy of learning physics to the goals of the men ($M = 16.73$, $SD = 4.65$) and women ($M = 14.07$, $SD = 4.39$), $t(127) = 3.14$, $p < .05$, Cohen's $d = .59$, with the men viewing physics

01. I enjoy learning physics. O Never O Rarely O Sometimes O Usually O Always	**16.** The physics I learn is more important to me than the grade I receive. O Never O Rarely O Sometimes O Usually O Always
02. The physics I learn relates to my personal goals. O Never O Rarely O Sometimes O Usually O Always	**17.** I think about how learning physics can help my career. O Never O Rarely O Sometimes O Usually O Always
03. I like to do better than other students on physics tests. O Never O Rarely O Sometimes O Usually O Always	**18.** I hate taking physics tests. O Never O Rarely O Sometimes O Usually O Always
04. I am nervous about how I will do on physics tests. O Never O Rarely O Sometimes O Usually O Always	**19.** I think about how I will use the physics I learn. O Never O Rarely O Sometimes O Usually O Always
05. If I am having trouble learning physics, I try to figure out why. O Never O Rarely O Sometimes O Usually O Always	**20.** It is my fault, if I do not understand physics. O Never O Rarely O Sometimes O Usually O Always
06. I become anxious when it is time to take a physics test. O Never O Rarely O Sometimes O Usually O Always	**21.** I am confident I will do well on physics labs and projects. O Never O Rarely O Sometimes O Usually O Always
07. Earning a good physics grade is important to me. O Never O Rarely O Sometimes O Usually O Always	**22.** I find learning physics interesting. O Never O Rarely O Sometimes O Usually O Always
08. I put enough effort into learning physics. O Never O Rarely O Sometimes O Usually O Always	**23.** The physics I learn is relevant to my life. O Never O Rarely O Sometimes O Usually O Always
09. I use strategies that ensure I learn physics well. O Never O Rarely O Sometimes O Usually O Always	**24.** I believe I can master the knowledge and skills in physics courses. O Never O Rarely O Sometimes O Usually O Always
10. I think about how learning physics can help me get a good job. O Never O Rarely O Sometimes O Usually O Always	**25.** The physics I learn has practical value for me. O Never O Rarely O Sometimes O Usually O Always
11. I think about how the physics I learn will be helpful to me. O Never O Rarely O Sometimes O Usually O Always	**26.** I prepare well for physics tests and labs. O Never O Rarely O Sometimes O Usually O Always
12. I expect to do as well as or better than other students in physics courses. O Never O Rarely O Sometimes O Usually O Always	**27.** I like physics that challenges me. O Never O Rarely O Sometimes O Usually O Always
13. I worry about failing physics tests. O Never O Rarely O Sometimes O Usually O Always	**28.** I am confident I will do well on physics tests. O Never O Rarely O Sometimes O Usually O Always
14. I am concerned that the other students are better in physics. O Never O Rarely O Sometimes O Usually O Always	**29.** I believe I can earn a grade of "A" in a physics course. O Never O Rarely O Sometimes O Usually O Always
15. I think about how my physics grade (in a course) will affect my overall grade point average. O Never O Rarely O Sometimes O Usually O Always	**30.** Understanding physics gives me a sense of accomplishment. O Never O Rarely O Sometimes O Usually O Always

Table 1. *Physics Motivation Questionnaire (PMQ; Glynn & Koballa, 2006)*

as more relevant to their future goals. There was not a significant difference in the self-determination for learning physics in the men ($M = 18.81$, $SD = 2.81$) and women ($M = 19.23$, $SD = 2.56$), $t(127) = -.82$, $p > .05$, Cohen's $d = .15$

There was a significant difference in the self-efficacy of the men ($M = 18.73$, $SD = 3.74$) and women ($M = 15.16$, $SD = 4.49$),

$t(127) = 4.80$, $p < .05$, Cohen's $d = .86$, with the men having higher self-efficacy in their physics ability than the women. Finally, there was a significant difference in the assessment anxiety of the men ($M = 13.47$, $SD = 4.89$) and women ($M = 9.93$, $SD = 4.86$), $t(127) = 3.90$, $p < .05$, Cohen's $d = .72$, with the women having more assessment anxiety than the men.

Of interest was the role of students' reasons for enrolling in the course in influencing gender differences and motivation. First, as indicated by a one-way ANOVA, there was not a significant difference in the motivation of students taking the course across the three reasons reported [$F(1, 128) = 2.57$, $p > .05$]. However, further analysis was conducted with independent-samples t-tests, which illustrated that there were differences in the motivation of students taking the course as a requirement for a program of study (e.g. to complete a chemistry major) ($M = 102.31$, $SD = 16.22$) or for medical school ($M = 94.97$, $SD = 18.67$), $t(124) = 2.09$, $p < .05$, with students enrolling in the course as a requirement for medical school having lower motivation. Student motivation was highest for students taking the course because they enjoyed physics, but the group size $n = 3$ likely contributed to the lack of significance found when comparing students taking the course for medical school or for enjoyment. Students taking the course for enjoyment had the highest level of motivation, while those taking the course as a requirement for medical school had the lowest levels.

A second one-way ANOVA indicated that there were gender differences in students' reasons for enrolling in the course [$F(1, 128) = 6.51$, $p < .05$]. As a result, a chi-square independence test was performed examining the relationship between these categorical variables. The chi-square statistic (106.46) and its small significance level ($p = .00$) indicated that it is unlikely that gender and reason are independent of each other. Thus, it can be concluded that there is a relationship between a person's gender and their reason for taking the course. This is an important result given that of the students enrolled in the course to fulfill a requirement for medical school, 63% were female and 37% were male, and that students who enroll in the course for this reason have the lowest levels of motivation. Of the students who enrolled in the course to fulfill a requirement for their program of study, 74% were male and 26% were female. No females, however, responded that they enrolled in the course because they enjoyed physics.

To better understand the existing gender differences, an ANCOVA was performed. Results indicated that when controlling for gender, motivation was not influenced by students' reason for taking the course ($F = 1.23$, $p > .05$, 3). However, when controlling for reason enrolled, there were gender differences in motivation ($F = 276.78$, $p < .05$, Table 3). Finally, there was a non-significant interaction between reason and gender.

Source of Variation	df	Mean Square	F	Significance
Reason	2	129.98	1.23	.30
Gender	1	2517.51	276.78	.04
Gender*Reason	1	9.09	.04	.85

Table 3. *ANCOVA Results*

Implications for Teaching

The results indicate that overall, the men had higher motivation in physics than the women, and differences in intrinsic motivation, view of the relevancy of physics to future goals, self-efficacy, and assessment anxiety contributed to this lower motivation. There were not significant differences in the extrinsic motivation and self-determination of the men and women, suggesting that both the men and women were similar in their extrinsic purposes for taking the course, and in the amount of choice and control they felt they had over their learning. Thus the results suggest that efforts should be focused on improving the intrinsic motivation, view of the relevancy of physics, self-efficacy, and assessment anxiety of women. Effect sizes (Cohen's d) that range from medium ($d = .5$) to large ($d = .8$) help illustrate the need to minimize these gender differences (Cohen, 1988). It is also useful to note that the variation in motivation within men and women is often as large as or larger than the difference between populations. This is quite common for gender-based measures. This indicates that along with gender differences between men and women, there is variation within populations of men and women. It is expected, however, that the suggestions provided below will help support the motivation of all students

Glynn, Taasoobshirazi, and Brickman (in press) recommend case studies that connect what students are studying in their science courses to their majors and goals for future careers as a way for students to see the relevancy of what they are learning to their future goals. In the course, the top three majors included engineering, biology, and chemistry, respectively (Table 2). Efforts to make physics relevant to students who select these majors, for instance, which make up almost 70% of the students in the course, would be extremely beneficial. High school and college instructors could assign projects in the form of case studies in which students select physics concepts and apply them to their prospective majors and careers. For instance, a student majoring in biology, and interested in pursuing medicine could focus on studying how blood flow through the arteries or the way a sphygmomanometer used to take blood pressure can be understood through pressure, volume, and resistance concepts in physics. The use of case studies that make physics more relevant to students would be particularly helpful for women as women, more than men, feel that feel that physics is irrelevant to their future goals (Murphy & Whitelegg, 2006). Considering not only students' majors, but their reason for taking the course would help support more effective case study projects. A biology student taking the course to attend medical school versus a biology student taking the course as a requirement to finish their program of study would select and benefit from different types of case study projects. Further, results indicate that females, more than males, elect to take physics as a requirement for medical school. Results also show that students who are taking the course for this purpose have lower levels of motivation in comparison to those taking the course as a requirement for their program of study or for enjoyment. Assignments and projects that allow females to see the application of physics to medicine may be beneficial for supporting their motivation

Another way that high school and college physics instructors can make physics more relevant to students is to implement the use of context-based physics instruction. This involves teaching physics by tying it to a real-world context in a way that allows students to make connections between the subject and its applications to their lives as citizens, family members, and students (Yam, 2005). In more recent years, a few textbooks have been designed to help support context-based physics instruction. Crawford et al.'s (2005) high school physics textbook, *Physics in Context*, is one example of a textbook that integrates context into the physics material and allows students to explore the physics content in light of real-life situations. The Supported Learning in Physics Project (SLIP) (Whitelegg & Edwards, 2001) has designed a set of eight books that helps high school and college instructors contextualize physics. These texts include *Physics for Sport, Physics in the Environment, Physics on a Plate, Physics in Space, Physics of Flow, Physics Phones Home, Physics on the Move,* and *Physics, Jazz, and Pop.* The books come with a teacher guide and evaluation pack, are published by Heinemann Publishers, and can be ordered on Amazon.com. The books explore major physics concepts in light of interesting and real-life scenarios. For instance, in one of the textbooks, *Physics for Sport,* equilibrium of forces is taught through the consideration of the way rock climbers use hand and foot holds at various angles on a climbing wall.

Unlike traditional textbooks which teach the concepts and then use real-life examples to help students better understand the material, the physics concepts in these texts are embedded within the contexts. Implementing context-based instruction at the high school and college level has been found to significantly increase the motivation and enrollment of all students in physics, but particularly that of women (e.g. Kaschalk, 2002; Wilkinson, 1999). Further, efforts to connect physics to students' everyday life experiences would also likely increase women's intrinsic motivation for learning physics, and help prevent women from viewing physics as impersonal, objective, and irrelevant to everyday life (Lye, Fry, & Hart, 2001). This is important given that only 16% of the females, in comparison to 54% of the males selected engineering or physics as their major. Further, while engineering was the top major, 88% of males in comparison to 11% of females were engineering majors.

Results of this study also indicate that high school and college physics instructors should work to decrease the assessment anxiety of women. One way to lower assessment anxiety is to minimize the competitive atmosphere typical of such introductory level physics classrooms (Mazur, 1997). Minimizing the performance-oriented nature of such classrooms and focusing students on mastery of the material they are learning reduces assessment anxiety (Pintrich & Schunk, 2002). The implementation of projects in the form of case studies as described above would be one way to help support mastery rather than performance goals. Further, enactive mastery experiences are a major source of self-efficacy (Bandura, 1997). In science, men tend to have more hands-on experiences than do women, particularly in physics (e.g. Jones, Howe, & Rua, 2000). For instance, in high school science classrooms, when working in groups with science materials, the men tend to be the ones who work with the lab equipment and direct activities, whereas the women tend to play the role of recorder (Shin & McGee, 2002). Providing women with more hands-on experiences through projects that connect what they are learning to their majors and career goals is one way to help increase their self-efficacy.

Also useful would be to examine the role of teacher efficacy on students' physics motivation and achievement (Riggs & Enoch, 1990), and how teacher efficacy influences the use and success of new curriculum methods. An instructor who has high self-efficacy is more likely to persevere with low-achieving and poorly motivated students, use new curriculum materials, and change instructional strategies (e.g. Kagan, 1992; Smylie, 1988). Thus, an instructor who has high self-efficacy will be more likely to implement the suggestions provided above.

Conclusion

This study examined gender differences in the key components of motivation in an effort to provide physics instructors with more directed support in improving the motivation of women in physics. Results suggest providing high school and college level women with (1) projects and assignments that connect the physics they are learning to their majors, career goals, and everyday life and (2) mastery experiences in physics, particularly those in the form of enactive hands-on experiences.

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A physics teacher candidate knowledge base

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What prospective physics teachers need to know and be able to do should be grounded in what their future students need to know and be able to do in order to live in and contribute meaningfully to life in a democratic society. National goals and standards reflect these needs, and have strongly converged in recent years on what it is that future teachers of science must know and be able to do. In response, a knowledge base has been established at Illinois State University to be used to guide the preparation of our prospective physics teachers.

It is sometimes noted that in order to teach well, teachers must possess an identifiable knowledge base. Philosophers as early as Aristotle addressed the question of what teachers need to know and be able to do in order to be effective at their chosen profession. Writing in *Nicomachean Ethics,* Aristotle saw the teacher's knowledge base as consisting of sophia ("wisdom") and phronesis ("prudence"). Sophia is the ability to think well about the nature of the world. It is used in the effort to discover phronesis, the ability to think about how and why we should act in order to accomplish a particular end.

In more recent times, the knowledge base of physics teachers has been described in the pages of this journal and elsewhere as consisting of three elements or components: content knowledge, pedagogical knowledge, and pedagogical content knowledge (Etkina, 2005). Content knowledge is knowledge of the discipline itself, and includes such things as procedural methods and possibly even dispositions. According to Etkina, content knowledge consists of "knowledge of physics concepts, relationships among them, and methods of acquiring knowledge" (2005, p. 3). Various documents define the content students should learn (e.g., *Benchmarks for Science Literacy*), and teacher preparation documents describe the role of the teacher (e.g., *National Science Education Standards*). Teachers must know what they are expected to teach their students, and probably substantially more as well.

Pedagogical knowledge, represents the "generic why and how to" of teaching. According to Etkina, pedagogical knowledge consists of "knowledge of brain development, knowledge of cognitive science, knowledge of collaborative learning, knowledge of classroom discourse, knowledge of classroom, and management and school laws" (2005, p. 3).

Pedagogical content knowledge (PCK) represents a situation-specific overlap of content knowledge and pedagogical knowledge. PCK deals with the "specific why and how to" of teaching a given discipline. According to Etkina, PCK consists of "knowledge of physics curriculum, knowledge of student difficulties, knowledge of effective instructional strategies for a particular concept, and knowledge of assessment methods" (2005, p. 3). PCK per se is hard to teach, and is often the result of many years of classroom experience (Wells et al., 1995). It can be described as "knowledge in action."

A Physics Teacher Candidate's Knowledge Base

A broader description of what a physics teacher candidate's knowledge, skills, and dispositions should be is provided in a less generic description as follows:

A. Content and Procedural Knowledge

The prospective teacher should have a broad and current understanding of the major content areas of physics. These include such areas as mechanics, electricity and magnetism, heat and thermodynamics, waves and light, optics, and modern physics. The prospective teacher's understanding will be at a level consistent with appropriate national and state standards, and includes a familiarity of the unifying principles of physics such as conservation of energy, momentum, mass, and charge. This presupposes that the prospective teacher will possess a general understanding of the closely allied fields of astronomy, chemistry, and mathematics, and will be aware of the major findings of the biological and environmental sciences.

The prospective teacher must have an accurate understanding of the processes of science, and its underlying assumptions. The prospective teacher should see scientific knowledge as emergent, and not absolute. Ideally, the prospective teacher will have learned content knowledge through methods of inquiry thereby acquiring closely associated procedural knowledge. The prospective teacher should have had an opportunity to experience the processes of scientific investigation: observing; defining a problem; hypothesizing from an evidence base; creating an experiment; identifying and controlling variables; collecting, graphically representing, and interpreting data; conducting error analyses; drawing conclusions; and communicating results. Knowledge so gained and communicated should help students understand that science is a way of knowing, and help them distinguish information that is not so derived.

B. Pedagogical Knowledge

The prospective teacher must understand what constitutes effective teaching, and be able to distinguish authentic teaching practices from practices so called such as instructing, informing, training, and brainwashing. The prospective teacher should have a demonstrable understanding of:

- **planning and preparation** – Prospective teachers must demonstrate an ability to prepare lesson plans for a variety of lesson types, create a unit plan, and deal with the broad implications of year-long curriculum planning. The prospective teacher must know how to integrate lecture-demonstrations, laboratory work, homework, discussion, presentations, assessment, student research projects, and out-of-class activities in a way that maximizes student learning.
- **quality teaching** – Prospective teachers must understand the difference between the transmission and constructivist views of teaching. They must understand the worth and power of constructivist forms of teaching, and the limitations of transmission forms.
- **inquiry practices** – Prospective teachers must be able to use inquiry practices effectively to help students construct knowledge from evidence, be familiar with concept change and its relationship to constructivism, be able to assist students participate in the procedures whereby knowledge of nature and technology is constructed.
- **cooperative/collaborative learning** – Prospective teachers must demonstrate an ability to utilize any of a number of cooperative and collaborative learning strategies, and be able to distinguish these strategies from traditional group learning.
- **problem-based learning** – Prospective teachers must demonstrate an ability to utilize problem-based learning as a means to promote problem solving and enhance critical thinking skills, and as a way to integrate diverse elements of the physical and biological sciences.
- **multiple representations** – Prospective teachers must demonstrate the ability to use a variety of representations to help students learn and understand the content of physics.
- **preconceptions and concept change** – Prospective teachers must demonstrate an understanding of a student's need for the construction of knowledge and its relationship to preconceptions derived though casual observations of the world.
- **learning cycles** – Prospective teachers must demonstrate an understanding of the relationship between learning cycles and classroom activities, and their effects on individual lessons and the broader curriculum. The complex interrelationship of lecture-demonstrations, laboratory work, homework, discussion, presentations, assessment, and student research projects, and out-of-class activities must be understood.
- **instructional resources** – Prospective teachers must demonstrate an ability to select, use, and adapt instructional resources to the needs of students.

C. Pedagogical Content Knowledge

Pedagogical content knowledge represents the "intersection" of content/procedural knowledge and curricular knowledge. It deals with the "specific why and how to" of teaching a given discipline – in this case physics. Physics teacher candidates should be familiar with the information contained in such books as the following: (1) *Teaching Introductory Physics* (Arons, 1997), (2) *Hands-on physics activities with real-life applications* (Cunningham & Herr, 1994), (3) *Five easy lessons: Strategies for successful physics teaching* (Knight, 2002), and (4) *Teaching introductory physics: A sourcebook* (Swartz & Miner, 1998).

The Physics Teacher Candidate Knowledge Base at ISU

Over the past 14 years, a detailed outline of a required knowledge base has been established for physics teacher education majors at Illinois State University. The current knowledge base was established on the basis of many year's experience with what high school physics teachers need to know, be able to do, and what dispositions they should possess in order to be effective. The knowledge base was established and periodically revised as part of a program accreditation review process that included addressing both the *National Science Education Standards* and the NSTA's *Teacher Preparation Standards.* The knowledge base in place today continues to guide decisions in course development and major requirements as it relates to teacher preparation. To see how these are implemented in the PTE program at ISU, readers may visit the online syllabi of six undergraduate science teaching methods courses at http://phy.ilstu.edu/pte/.

1. Knowledge of Curriculum

The prospective teacher must possess a broad understanding of the practices of physics teaching as reflected in the aims, goals, and objectives of both national and state science teaching standards. This includes a working knowledge of long-term and short-term planning required for teaching an inquiry-based program; an ability to align teaching goals, objectives, and assessment with these standards; an ability to provide needs-based rationales for inclusion of material in the curriculum grounded on student interests, community values, teacher strengths, and societal needs. The prospective teacher must be able to identify the various curricula that are available for physics teaching.

2. Understanding What "Scientifically Literate" Means

The prospective teacher must have a working definition of what it means for a person to be scientifically literate, and must be so. That is, the prospective teacher will have a well-founded "knowledge and understanding of scientific concepts and processes required for personal decision making, participating in civic and cultural affairs, and economic productivity" (*National Science Education Standards,* 1996, p. 22).

3. Understanding Students

The prospective teacher must be aware of the psychological basis for effective science teaching. The prospective teacher must also demonstrate an ability to come to know students as individuals, to assess their knowledge and background, and show a willingness to work with parents to serve the best interests of students. This includes dealing effectively with different student learning styles, sources of interest, motivation and inspiration, and cultural and emotional differences. This also includes identifying and correcting learning difficulties where possible using personal knowledge and experiences, or through conferral and referral.

4. Classroom Management Skills

The prospective teacher must demonstrate excellent student management skills by maintaining classroom discipline using a firm, fair, friendly, and focused demeanor. The skilled classroom manager will effectively present lessons so that students will perceive time in the classroom as of significant positive value. The atmosphere so maintained should not be rigid and regimented, but should be flexible and conducive to student inquiry.

5. Communication Skills

The prospective teacher must be an excellent and effective communicator, both in conducting instruction and in receiving and responding to information. The prospective teacher will demonstrate excellence in communication by using proper vocalization (diction, grammar, enunciation, and projection). The prospective teacher will demonstrate effectiveness in communication by presenting information systematically and logically, by questioning students using appropriate means (using a variety of question types, making effective use of wait time, etc.), and by listening and responding well to students' questions, answers and comments.

6. Knowledge of the Teaching-Learning Relationship

The prospective teacher should be aware that teaching is what teachers do, that learning is what students do, and that there might be no direct relationship between teaching and learning. The prospective teacher sees the role of teacher as that of a science guide who facilitates learning, and is aware of the major principles of learning.

7. Scientific and Philosophical Dispositions

The prospective teacher should demonstrate scientific dispositions (beliefs, behaviors, attitudes, values) and should be able to engage students in activities that help clarify the need for a consistent scientific ethic. The prospective teacher should demonstrate the habits of mind closely associated with the intellectual rigor of scientific inquiry and attitudes and values conducive to science learning. The prospective teacher should understand the assumptions and limitations of scientific knowledge.

8. Social and Technological Context

The prospective teacher must demonstrate an understanding of and an appreciation for the broad applicability of physics to real-world situations. Prospective teachers must be able to provide a rationale for including physics in the school curriculum as it relates to any area of life in general, and technology in particular. The rationale must deal with the value of scientific knowledge to their students, to society, and to the scientific professions. The prospective teacher must demonstrate an understanding of the relationship between science and technology, and the relationship between scientific values and social values.

9. Learning Environment

The prospective teacher should have an understanding of how to create among students a disposition in favor of science, and scientific ways of knowing. The learning environment should be physically and emotionally safe, and one in which questioning is valued as much as knowing, and process is valued as much as product. The prospective teacher should know how to provide stimulating learning environments that develop a community of learners who share time, space, and materials to learn science. The prospective teacher should know the meaning, differences, benefits, and consequences of competitive, cooperative, and individualistic learning atmospheres. The prospective teacher should know the effect of expectations on student achievement, and how to exert appropriate classroom control measures.

10. Active and Engaged Learning

The prospective teacher should have an understanding of how to teach in active and engaging ways that create and sustain student interest in science generally, and in physics in particular. This engagement should sustained student participation in learning activities, should include learning cycles, and involve students in cooperative group processes.

11. Student Assessment

The prospective teacher should have an understanding of the goals and procedures of both "regular" and alternative/authentic assessment. The prospective teacher should know how to use a variety of means to assess stated objectives that are fair, valid, and reliable, and consistent with the decisions they are intended to inform. The prospective teacher will see ongoing assessment of student learning as a valuable adjunct to teaching. The prospective teacher should be aware of sources, and uses for standardized tests, and be able to accurately interpret results.

12. Self-Assessment and Reflective Practice

The prospective teacher should demonstrate the habit of regular self-assessment – reflecting objectively upon personal teaching practice with an eye toward improving professional practice and increasing student learning. The prospective teacher will engage in ongoing assessment of personal teaching practice, in cooperation with formative feedback provided through clinical supervision. The prospective teacher should demonstrate the disposition of a life-long learner in all areas of professional life.

13. Technology of Teaching

The prospective teacher should have knowledge of and first-hand experience with the wide range of instructional and scientific technology to be used in the classroom. This includes demonstration and laboratory equipment, computers and their applications, microcomputer- and calculator-based laboratory equipment, and the software associated with accessing the Internet to be used by students.

14. Professional Responsibilities

The prospective teacher should abide by a code of professional ethical conduct. It is incumbent upon the teacher to improve educational practice personally, and at the level of the school and the wider academic community. The prospective teacher should perceive professional organizations and publications as instrumental in professional improvement.

15. Nature of Science

The prospective teacher must possess a broad understanding of the nature of science. The teacher candidate must be able to define the values, beliefs and assumptions inherent in the creation of scientific knowledge within the scientific community. This includes being able to: distinguish science from other ways of knowing; distinguish basic science, applied science and technology; identify the processes and conventions of science as a professional activity; and define acceptable evidence and scientific explanation.

16. Responsive Teaching

The prospective teacher must know what it means to be a culturally responsive teacher in order to ensure participation of all students independent of gender, disabilities, and cultural differences. The prospective teacher must teach in such a way as to provide for gender differences, physical and mental disabilities, and racial/ethnic differences.

17. Knowledge of Authentic Best Practices

The prospective teacher must have a thorough understanding of authentic best practices, and how they relate to how students learn science. As such, the teacher candidate will understand the importance of dealing effectively with student preconceptions, will understand how to use inquiry practices effectively, will understand the meaning and roles of student metacognition and self-regulation, and will be well versed in the use of cooperative/collaborative learning practices.

18. Knowledge of Generic Best Practices

Many teaching skills come from practical experience and are not well grounded on a research base. Much of what is handed on as "grounded in research" tends to be nothing more than idiosyncratic anecdotal experience – it constitutes the craft wisdom of teaching. Nonetheless, these best practices so-called constitute the "art of teaching" and often can provide a number of valuable alternative avenues for effective teaching.

Uses of this Knowledge Base

This knowledge base can be used in a variety of fashions, not the least important of which is as a guide for developing or reformulating physics teacher education programs. Another way that this knowledge base can be used is to help school administrators make informed hiring decisions or prospective teacher candidates to make an informed choice about the school in which to enroll. It can also be used by in-service teachers to self-assess.

It's not uncommon that school administrators such as superintendents, principals, and department chairpersons need to call upon one or more experts in making a hiring decision. Often that expert is an established physics teacher. However, when such an expert is not available as when in replacing one solitary physics teacher with another or having only a less qualified cross-over physics teacher on staff, then reference to this knowledge base can provide that administrator with the background he or she needs for making meaningful inquiries into a teacher candidates' preparation.

Students seeking the best teacher preparation program in which to enroll might also want to consult this knowledge base in an effort to determine which of the elements contained herein is, in fact, addressed or ignored in a given physics teacher education program.

Reflective practice consists of self-assessment and auto regulation. In-service teachers who wish to improve their practice will compare their performance against established standards, and the current knowledge base can serve as one such set. Professional development plans can be based on any deficiencies that have been identified in comparison with this knowledge base.

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The motivation and recruitment of physics students and teachers

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People interested in science are rightly concerned about a potential decline in the number of scientists. Institutions preparing teachers and scientists are now searching for different pathways for recruitment programs and ways to improve interest in physics and technology. At our department we started a recruitment program with the aid of the Ministry of Education and The European Social Fund – Human Resources Development. In this paper these projects are presented, examples of major activities are shown.

Introduction

Some aspects of teaching that influence the lack of interest in the teaching profession in the Czech Republic include the following: the low social status of teachers, poor pay, stress, and work with disruptive pupils. Teachers complain of a lack of support and respect from both students and parents. Working as a physics or science teacher can be a very demanding career. Science teachers need to understand their subject (physics or science), the structure and the nature of their discipline, teaching methodology, student psychology, and human biology too.

Improving students´ performance in physics requires qualified competent teachers in every classroom who are able to demonstrate the importance of science in general and physics in particular, and able to motivate students to become researchers or physics teachers. The secondary school is perhaps the most important place for the recruitment of these students.

Institutions preparing teachers and scientists are now searching for different recruitment strategies to stimulate an interest in physics and technology. Attracting young students to scientific research, physics and technology is a topic of great importance. I would like to describe our main activities which aim at solving some of these problems. Within our science department we have started a recruitment program with aid from the Ministry of Education and the European Social Fund – Human Resources Development.

Project Nr. 1 – Media Emphasis on Recruitment (http://www.projektmedved.eu/)

The first recruitment project at the Faculty of Science in Olomouc was "Media Emphasis on the Recruitment of Science Students and Perspective of Scientific Branch Studies." The main problem is that there is not sufficient knowledge among the general population about the importance of science and research. High school students prefer university studies oriented toward economics and the humanities which are associated with future jobs that will have more prestige and higher salaries. The first aim of this project is to have closer cooperation with the media such as television or newspapers. More information about science and activities in the field of teaching, methodology and future trends in techniques and technology are to be presented in journals, newspapers or television. The second aim is to have an "open university" – a university that opens its doors to the public and organizes various activities, such as open houses, excursions, and presentations of successful research for both young and old.

Figure 1. *Logo of the project*

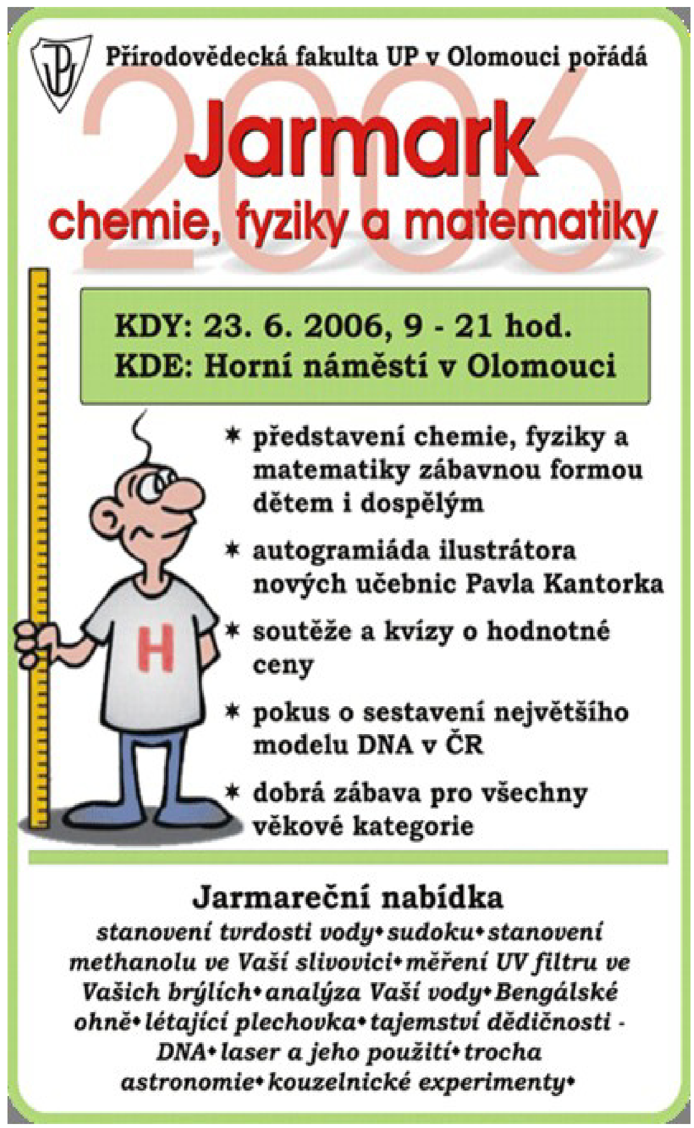

Figure 2. *Invitation card to the trade fair*

Figure 3. *Trade fair stand*

Our university will make better use of the outdoor classroom as a context for teaching and learning. Our main activity is the Physics, Chemistry and Mathematics trade fair (http://ach.upol.cz/jarmark/).

The fair takes place in front of the Town Hall on the main square in Olomouc. Physics, chemistry and mathematics students prepare many demonstrations and puzzles, and everybody who is walking around the town square can attempt to do these experiments themselves. Fig. 2 shows the invitation card to this fair; Fig. 3 is an example of a stand. This fair became very popular among pupils. School classes come in the morning and later we see children of all ages with their parents or grandparents visiting the fair. You can find photos and videos of this event on the web page mentioned above.

- **Physical Kaleidoscope** (http://kaleidoskop.upol.cz/)

Figure 4. *Kaleidoscope – experiments*

In November high school students are invited to our department, and researchers and teachers prepare a day-long programme. Kaleidoscope consists of lectures and experiments, and excursions to the research laboratories of the Departments of Experimental Physics, and Optics and the Nanotechnology centre. Lectures are presented on a wide array of topic, e.g. astronomy, optical illusions, over the frontier of school experiments, nanotechnology in practice, plants and stress and low-cost and high-tech physical experiments (see Fig.4). Field trips are organised too – one can visit the research laboratories of quantum optics, the laser laboratory and the holography, electronics and biophysics and also the Mössbauer spectroscopy and the nanotechnology centre. We prepare seminars for practicing teachers for example about Interactive Physics or the Mathematica Calc Centre (www.ictphysics.upol.cz).

- **Cooperation with the Debruillards groups**

Motivating students plays a key part in our innovations of educational strategies and methods. We can apply many motivational approaches during teaching science. Cognitive motivational teaching methods have an important status amongst them. Applying science through simple experiments at school is one of the most important motivational tools that can be used.

An example is the principal method of research in experimental and theoretical science. A science experiment is an artificial natural phenomenon under controlled conditions with the objective of recognising a natural law, not yet discovered, which the natural phenomenon follows. Students should participate actively in doing simple scientific experiments. Simple experiments can and should be done and demonstrated by the students themselves. From the view of constructivism, there is a need to aknowledge and use students' preconceptions, in creating independent spontaneous experiments. Simple experiments therefore have to be easily accomplished. You can find the philosophy of the Young Debrouillards at: http://kdf.mff.cuni.cz/Heureka/en/index.php.

The basic requirement of the Young Debrouillards principal is a set of simple and entertaining experiences to fascinate the youth. In this way they learn to develop their analytical mind and their intellectual skills. Creativity is no longer regarded as a discrete skill required for art, drama or music, but rather it is seen as central to a child´s ability to work imaginatively and with purpose, to judge the value of their own contributions and those of others, and to fashion critical responses to problems across all subjects in the curriculum. (Designing technologies to support creativity and collaboration. Futurelab, 2004).

Teachers teaching secondary school students may follow three common principles:

1. Using scientific processes,
2. Incorporating leader-guided creativity, and
3. Using inexpensive and non-sophisticated materials.

The aims are as follows: to allow the development of the child's autonomy, to propose entertaining activities to the child and so stimulate the child's exposure to scientific phenomena in the everyday environment, to develop the child's curiosity and analytical mind and to educate the whole family through the child to help students achieve scholarships and increase their social mobility.

From the history of the project I want to underline key inventions.

- The project concentrates on physics education for the age group of 12-15. It started 'from the bottom up': from teachers at schools. It is now a common project. It has lasted for more than 16 years - the project started in about 1991 and from the activity of just a few people it expanded into a project including several hundred of active participants. Its aim is to cultivate not only the teaching of physics but also interactions between teachers and pupils in general.

- The title Heuréka (which, in English, means Eureka!) reminds us of the heuristic method of teaching. But it does not mean that Heuréka is limited to the old ‘learning by discovering’ approach (which was criticised for, e.g., ignoring pupils’ preconceptions, context of learning, etc.).
- The main idea of the Heuréka project is based on constructivism. We can see these trends in the educational programmes of other western countries as well.
- The need to improve the teaching of physics is at the centre of our interest and has been very intensive in the last years. Some research studies have been done, but Heuréka is only a small part of innovative activities in our schools.
- The participants try to allow pupils to discover physical principles and phenomena by themselves. Our task is to make them active during the learning process. We don’t want to create passive consumers of information passed on in a teacher-centred classroom.

The teacher’s position and role in the classroom has changed – the teacher is not the leader and the source of information anymore, but more a moderator. He/she should gently steer the course of the lesson and lead the pupils to their discoveries and discussions. The teaching process starts with a problem – it can be a question, an experiment, an exercise - and the students are allowed to discuss what they have seen, ask questions or present hypothesis. They must find ways to disprove their assumptions; they must formulate their results and answer the questions. A very important aid in learning is making mistakes as a step in the process of finding results. The educational process is closer to children´s every day life. They develop competency in communication, discussion, practical skills and living in society. The class environment reflects real situations.

Homework is a significant part of the education process. It can be a numerical problem or the solving of a problem which requires that the child does an experiment or constructs of a simple appliance. When doing the homework, the children can consult with their parents, grandparents or friends etc. Sometimes it happens that the whole family is discussing an interesting physics problem

Experienced teachers prepare written materials for the new-comers participants of the project and so a detailed methodology of education is developed and lesson scenarios are recommended.

Project Nr. 2 – Research of New Forms of Competitions in Fostering the Creativity of Youth

The second project at the Faculty of Science in Olomouc is the project “Research of new forms of competitions in fostering the creativity of the youth aimed at motivating them to do research in science, especially in physics, mathematics and chemistry.” The aim of this project is the research and development of new forms of competitions, so that students of all ages will be motivated to take an active part in research and other activities at university departments. Students practice the methods and processes of research workers. To recruit students more activity and creativity and therefore we need new competitions. One task was to develop a way how to communicate with practising teachers and so we have courses for them. We teach them how to make physics fun for all the students and how to conduct new programs in the classroom. We speak positively about teaching at all levels. Our recruitment program includes summer teaching schools and invitations to university days etc. We are trying to develop a closer partnership between high school and university and provide opportunities for professional development. The main activities targeted at high school students are:

- School projects (http://isouteze.upol.cz)

For example: Do you like to take photos? Physics simulations – programming

- Technical Kangaroo
- Correspondence Seminar in Physics - Olomouc Physics (http://isouteze.upol.cz/index.html)
- Chemistry Project Labyrinth

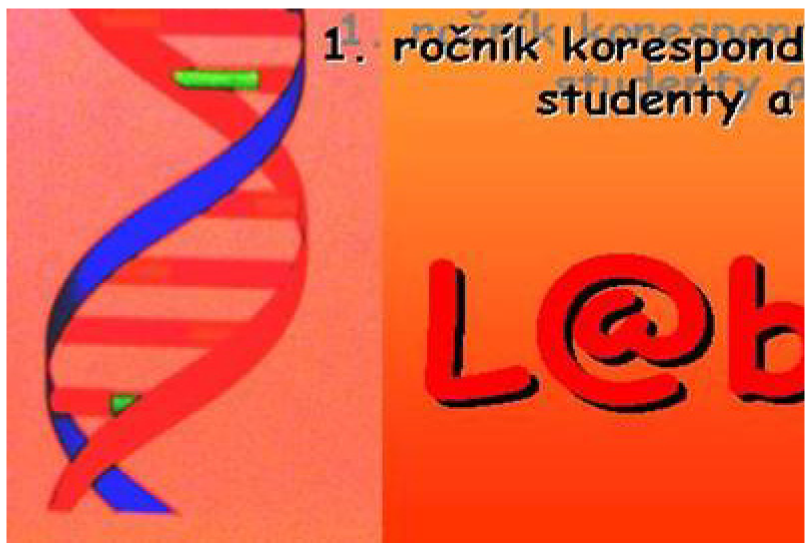

Figure 5. *Chemistry Project Labyrinth*

Labyrinth is a web-based game and a competition involving chemistry problems (puzzles) for secondary and high school students. The communication is done via the Internet.

- Fermi Questions and Inventor (http://isouteze.upol.cz/fermi/index.html)

Fermi questions is a competition for high school students. Fermi questions are named after Enrico Fermi, a Nobel Laureate in physics, who was famed for being able to do order-of-magnitude calculations in his head. For example, after watching the first atomic bomb explosion, he immediately calculated that the strength of the explosion was equivalent to the explosion of 20 kilotons of TNT. These kind of calculations are still very important because an approximate answer will often dictate the amount of resources required to attack a problem. Fundamental to the solution of these problems is a skill called critical thinking - essentially a method of attacking such problems in an orderly, logical way. There are several advantages to this procedure:

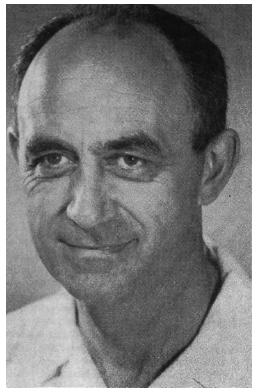

Figure 6. *Enrico Fermi*

- Mathematics (straight) – where the answer can be calculated using a calculator or computer but, since such aids are not allowed in the competition, it forces the student to consider other routes to provide a reasonable answer
- How answers from one problem relate to other problems – as with many facets of life, an answer to one problem leads to many other choices and problems.
- How having solutions to problems relate to 'real life', for example, a problem might ask for an estimate of the amount of gasoline used by passenger cars in France, how an increase in gas mileage would relate to a decrease in green-house gas production, and how the amount of water produced by same relates to other items such as rainfall or filling of swimming pools. (http://www.soinc.org/events/fermiq/fermiguide.htm)

Some questions that were answered:

1. How many hairs are on your head?
2. What is the mass of a fully loaded Boeing 747?
3. How many minutes do middle school students in your town spend on the telephone?
4. How many 100-Watt light bulbs have the same energy output as the Sun?
5. How many jellybeans fill a one-litre jar?
6. What is the mass in kilograms of the students' bodies in your school?

The evaluation was based on the accuracy of the estimation, the number of supplementary steps in the solution to the problem (number of other questions and answers), originality and the presentation of the work.

Figure 7. *Logo of Network of Youth Excellence*

- **Research Scientist** http://www.badatel.upol.cz/

The project researcher is a part of the initiative Network of Youth Excellence, sponsored by UNESCO. The network will offer the possibility of the exchange of experiences amongst various initiatives worldwide. International organisations which take part are:

Badatel (Czech Republic)
Barcelona Science Park (Spain)
Comenius University (Slovak Republic)
Educational Centre for Gifted Youth (Lithuania)
Estonian Academy of Young Scientists (Estonia)
Hands-on Science (Network)
Irish Centre for Talented Youth (Ireland)
Latest Information on Nature and Science using Information Communication Technologies/LIONS-ICTS/ (Nigeria)
World Academy of Young Scientists (Network)

The main idea is to give research experience to students of secondary and high schools. This will result in adolescent-aged students exploring life and having the opportunity to do research at the university will give them the chance to find a place in a new social environment. You can find the major aims and objectives of the Network at www.nyex.info.

Research students take part in research projects in the field of biophysics, chemistry, applied physics, nanotechnology and mathematics (http://badatel.upol.cz). There are now 58 students taking part in this project.

Project Nr. 3 – Qualitative Development of a Programme for Teachers of Physics (http://exfyz.upol.cz/didaktika/oprlz)

In addition to these projects, the Europian Union project “Qualitative development of a programme for teachers of physics” at the Department of Experimental Physics should be mentioned. The content of the pre-graduate education programme is changing. New subjects are included and new methods are being taught, based on constructivism and cooperative learning. The application of physics, techniques and technology in everyday life and the solving of real-world problems is being emphasised in all parts of education. Some of the new subjects are for example: Physics, techniques and nature, Simple hands-on experiments, Environmental physics, and Computer-based experiments.

New educational materials and tutorials are prepared and seminars for teachers are organised. They will learn about new ways of recruitment, teaching methods and about the initiatives of our university.

Conclusion

All these projects mentioned above and the activities at our department help us to answer the question: “What is the best and most practical way to recruit and prepare future physics teachers and researchers?” We will be able to answer this quesstion on our experience maybe in the next four or five years. Now we can see more interest pupils in the age of 16 or 17 and a growth in the number of young teachers that participate in educational programmes at our university. This is the first step in the recruitment programme. In this year more than 20 high schools in our district started a closer cooperation with our faculty – the students are thought in our laboratories and university teachers are invited to high school seminars. I think that the cooperation high school-university is a good way in the recruitment of physics teachers and researchers.

The future more than ever before will depend on a well-educated population. It is vital to find concrete ways to improve the teaching of science and in our opinion, the best teaching strategy is to replace the teacher-centred model with a student-centred model.

Teaching is not only a profession, it is a mission. We must think about teaching as a higher goal, a prestige job and something not everyone can do. Our prospective teachers and researchers must have experience of good teachers, who showed them the applicability of physics in everyday life. The teachers themselves must be interested in physics and science and not just teach to gain the advantage of a two-month holiday.

In our opinion students are motivated by curiosity and wonder during their lessons. A good understanding of the problem can also be a way to motivate children to study. With nontraditional and outdoor activities we can show them that science can be fun and understandable. The aim is to bring the school environment and activities closer to the students´ experiences and the problems of practical life, techniques, work, and employment. It is necessary to show the application of knowledge in techniques because techniques, technology and physics are not the same but they cannot exist without each other. The basis is the students' activity; however, not just by asking and answering their own questions but also through practical activities, through hands-on experience nad taking part in the research programme of the University and research centres. Physics education is not a constant but a variable. It changes in direct relation to the developments in the society of which it is a part. The same problem of a low level of positive attitude toward science also appears in the whole society. Therefore science education needs powerful innovations in terms of strategies and teaching-learning technologies. The key finding of this project is the importance of the new status of teacher preparation in the Czech Republic with the emphasis on better use of the outdoor classroom.

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