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JOURNAL OF PHYSICS TEACHER EDUCATION ONLINE

Journal of Physics Teacher Education Online is dedicated to investigating and documenting significant issues and challenges in the education of physics teacher candidates, and in the professional development of inservice high school, college, and university physics teachers. The purpose of *Journal of Physics Teacher Education Online* is to establish a forum through which the scholarship of teaching and learning can be exchanged widely and built upon. The hope is to support the development of new models of physics teacher preparation and education that foster deep and lasting understanding as well as quality teaching, while underlining the character of teaching itself as a scholarly endeavor worthy of recognition, support, and reward. With a focus on the scholarship of teaching, the journal seeks to generate discussion and promulgate sustainable, long-term changes in educational research, policy and practice. Journal articles will foster deep, significant, lasting learning for physics educators and improve their ability to develop teacher candidates' understanding, skills, and dispositions, and to assist inservice teachers as they grow through professional development activities.

Physics teacher educators, often only one individual working within a department of physics teaching methods courses with the intent of preparing future teachers, are frequently isolated from their peers due to a lack of a medium of exchange. As a result, those who engage in innovative acts of teaching do not have many opportunities to share their work, and to build upon the work of others. Without an opportunity to share with like-minded peers, teacher educators are likely to remain isolated, and unable to benefit from or advance the work of the physics teacher education on a broader basis. Fortunately, renewed public interest in education reform, the development of teacher preparation standards, and some inspiring models from physics teacher education programs around the country provide hope that the time is right for change. The work of educating future physics teachers often involves significant shifts in thought and practice. For physics teacher education faculty, physics teacher preparation is a private act, limited to the teacher and students. Such practice is rarely evaluated by professional peers, again, due to a lack of readily and widely accessible forum to exchange ideas and share procedures.

The time is right for the introduction of a peer-reviewed journal for physics teacher education. With efforts beginning nationwide to reformulate physics teacher preparation (such as the PhysTEC program), the *JPTEO* will serve as a valuable forum to enhance that process. *JPTEO* is intended primarily for those with a stake in physics teacher preparation: employers, physics teacher educators, high school physics teachers, college and university physicists, PhysTEC members, and PER faculty to name but a few. Not only will these individuals be the main readers of *JPTEO*; they also will be the main contributors. Contributions are now being solicited for upcoming issues of *JPTEO* which will be published on a quarterly basis beginning with June 2002. Articles are now being sought that deal with any phase of teacher candidate preparation or continuing professional development of inservice secondary physics teachers.

As with any new publication, there are bound to be difficult times, but especially at the outset. Creating and maintaining any sort of journal requires a commitment from its readership to submit articles of interest and worth in a timely fashion. Without such contributions, any journal is bound to fail. It is my hope as founder and editor-in-chief of this publication that you will help to see that the *JPTEO* becomes a forum of lively exchange by submitting articles for consideration and publication.

Detailed information about contributing to *JPTEO* can be found on the journal's website at *www.phy.ilstu.edu/jpteo.*

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EDITORS & REVIEWERS

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A comparison between traditional and "modeling" approaches to undergraduate physics instruction at two universities with implications for improving physics teacher preparation.

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"Modeling instruction" was adapted and implemented in undergraduate algebra-based physics courses at California State University Fresno and the University of New England. Comparisons of standardized assessments were made between traditionally taught general physics sections and a "modeling" physics section at the two universities over a four year period. An essential ingredient in this enterprise was the preparation of lab instructors faithfully trained in the modeling approach. The motivations for this effort were twofold: 1) To help determine if an undergraduate general physics sequence might benefit from the adoption of multi-representational instructional approach addressing alternative conceptions in a more constructivist manner. 2) Development of an experiential learning environment to train physics educators in the modeling process.

Students in the modeling sections achieved, on the average, a one-half standard deviation or higher score over their traditional lecture counterparts, as measured by standardized assessments. Most significantly, the normalized gain on the Force Concepts Inventory for the modeling students was two times greater than their traditional-lecture peers at both schools. The lab instructors universally found modeling instruction to be a major improvement over traditional teaching approaches. The majority of these teachers are enthusiastic modeling converts in their own classrooms today.

The "modeling method" of physics instruction has improved student scores compared to traditional instruction based in part on standardized assessments in high school physics classrooms around the country[1]. But will the modeling approach work in a larger university classroom? What are the pitfalls of trying to "scale up" a lab-intensive high school instructional approach to a traditional three lecture/week, three-hour lab section college course? What impact can be made on retraining experienced physics educators and providing experiential teacher training to new inexperienced teachers?

This paper documents the adaptation and implementation of the modeling approach by the principle author at two similar universities on opposite coasts of the United States. The effort was evaluated through class averages on four nationally recognized standardized assessments developed for mechanics. The content of the traditional and modeling sections was kept the same during the study. Only the instruction process differed. This paper attempts to provide objective, quantitative evidence from side-by-side comparisons of two universities indicating the differences between traditional and modeling instruction in terms of student achievement. Additionally, feedback from the lab instructors trained in the modeling approach was used to determine the impact of the instruction in their personal teaching habits.

The two comprehensive universities involved in this study were California State University Fresno (CSUF) and the University of New England (UNE). CSUF is a public university near the geographic center of California with a total enrollment of 18000 students. UNE is a private institution located on the southern coast of Maine with an enrollment of 2500 students. CSUF is a minority serving institution with 48% white, non-Hispanic background and UNE is 95% white, non-Hispanic background institution. Other than location and diverse populations, the introductory general physics populations at both schools are remarkably similar, comprised primarily of life sciences and pre-physical therapy majors. The average combined SAT scores for physics students at both schools was around 1050 at the time of this study. During the study, algebra-based physics instruction consisted of three one-hour lectures and a weekly lab (3 hours at CSUF, 2-3 hours at UNE). Lecture sections at both schools ranged in size from 40-80 students. Lastly, most students ($\approx$ 70%) at both universities self-reported taking high school physics, algebra and trigonometry. Modeling instruction was used by the first author (JV) in lecture for all four years of the study.

The course was designed such that much of the modeling "cycle" was completed in lab, from pre-lab discussion to consensus development. Lab instructors played a pivotal role in the development of physics understanding of the students, thus emphasis was placed on training lab instructors in the modeling process. Following the recommendations by Arons[2], "operational definitions" and lab activities culminated in the development of mental pictures and definitions needed to describe the experimental datum. This approach is in opposition to more traditional instruction in which mathematical derivations are typically provided first and confirmed in lab. Our lab instructors were expected to employ Socratic dialog[3] to elucidate core models to describe paradigm lab activities. The models were then applied and validated in workbook and "deployment" activities in class. Model deployment consisted of interesting and hopefully even amusing activities (e.g. "kissing an egg with a mass on a spring") to test the student-generated models. Any representation was allowed to make a prediction, be it verbal, graphical, diagrammatic or mathematical.

The modeling cycle JV adapted to the algebra-based general physics sequence at CSUF and UNE used lecture time to further develop lab models and focus on communicating his students' understanding through whiteboard presentations. The lab instructors (either JV or his modeling trainees) were responsible for "mining" graphical, diagrammatic, and mathematical representations from the students after the lab was completed. Since success hinged on lab instructor expertise[4], we spent as much time in pre-lab preparation as the instructors spent in lab with their students. The lab instructors used their newly developed skills in the modeling process with their charges. In some cases alternative conceptions of the lab instructors had to be confronted first before they were able to successfully guide their students through the lab activities. The models were revised further in class and applied to workbook activities and class discussions. This instruction process represented a major shift from an interactive lecture style JV had previously developed.

From 1995-1998 JV had employed interactive engagement strategies such as "Peer Instruction"[5], "Class Talk"[6] and numerous student-popular demonstrations to address common student alternative conceptions. To determine student comprehension of the coursework, JV used the normalized "gain"[7] of a standardized assessment, the Force Concepts Inventory (FCI[8]), before and after taking first semester physics. At CSUF mechanics is offered each semester to three sections taught by different instructors. JV's students had achieved an average "Normalized Gain" of 0.22 after a significant investment in interactive class development and three years (six consecutive sections) of instructing mechanics. This result was identical for the two other traditional lecture sections taught at CSUF and equal to the national average for a traditional physics lecture/lab course[9]! The result was surprising and discouraging to JV who had fully expected larger FCI gains from the interactive engagement nature of his course[10].

JV participated in modeling instruction training sponsored by Arizona State University in the summer of 1998 and initiated a pilot study in the fall of '98 to compare the efficacy of modeling instruction versus traditional instruction. A highly rated, experienced instructor (coauthor GM) taught one section using traditional lecture relying on an algebra-based college physics text. JV used the modeling approach to teach a different section without a required text. Additionally JV taught one modeling lab section with computer-supported paradigm lab activities that preceded model development (in accordance with the modeling cycle). All remaining lab sections relied on a traditional confirmation lab workbook developed for over 20 years at CSUF.

At the time this study was undertaken modeling curriculum was refined only through circular motion.[11] To accommodate student articulation from other CSU campuses, JV employed resources, with permission from the publishers, including Randall Knight's studio physics workbook[12] for thermodynamics, Richard Hake's S.D.I. labs[13], and Dr. Lillian McDermott's physics tutorials[14] for rotational dynamics. The traditional and modeling sections covered the same core content, only the approaches were different. Both instructors used the same quizzes, including such standardized assessments as the FCI[15], the Test for Understanding Graphics and Kinematics (TUG&K[16]), and the mechanics baseline test (MBT[17]). At the time of this study no relevant thermodynamics inventories were available. Consequently the last quiz and final exam consisted of mutually agreed upon word problems.

Figure 1 indicates that the modeling students had improved conceptual mechanics comprehension over their traditional lecture/lab colleagues, with no difference in quantitative reasoning skills.

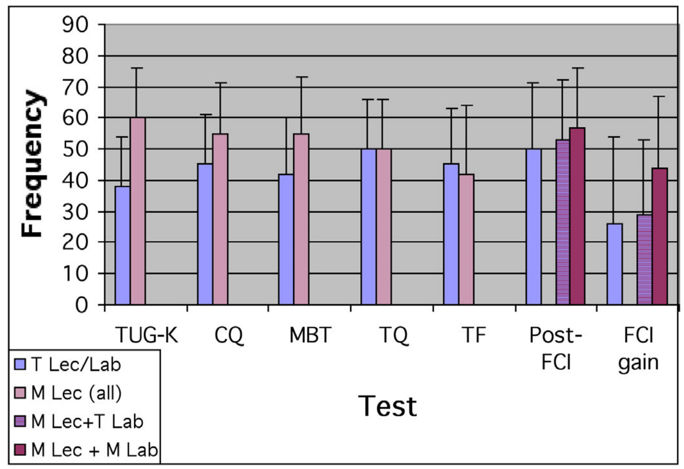

Fig. 1. *CSUF Fall '98: The columns reflect four combinations of lecture and lab students could take. Traditional lecture and lab, "T Lec/Lab" (N = 57), and all modeling students regardless of lab, "M Lec (all)" (N = 44). The modeling class was further broken down into students taking the traditional lab, "M Lec+T Lab" (N = 24) or modeling lab, "M Lec+M Lab" (N = 20). Error bars represent one standard deviation. Though the modeling and traditional lecture classes had similar FCI post-test averages, the modeling class pretest FCI average initially was lower. Therefore the modeling class/lab students achieved the highest gains. TUG&K = Test for Understanding Graphs and Kinematics[16], MBT = Mechanics Baseline Test[17], FCI = Force Concept Inventory[15], CQ = Conceptual Quiz, TQ = Traditional Quiz, TF = Traditional Final Exam.*

The encouraging initial outcomes, especially in lab, prompted an expansion of the modeling curriculum to include all introductory mechanics lab students in spring of 1999. Another side-by-side comparison was made between the modeling class and students taught by a different experienced traditional lecture instructor (coauthor FJ, T1 on Figure 2). Pre- and post-FCI testing also included the remaining traditional lecture section (T2). There were three major changes to the study: 1) The Force & Motion[18] diagnostic exam was employed for the second quiz, 2) JV did not teach any lab sections, 3) and the final exam could not be compared as the instructors opted to use different tests. JV was re-

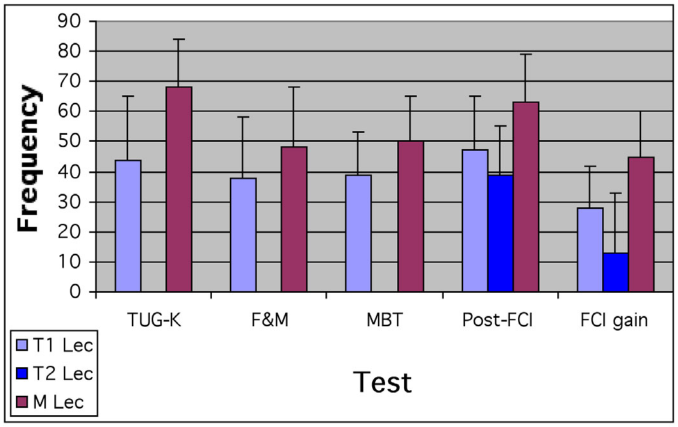

Fig. 2. *CSUF Spring '99: Students from all three general physics sections took the modeling labs. The two traditional lecture sections, T1 (N = 54) and T2 (N = 66), achieved marginal FCI gains. The gain by the modeling section (N = 33), M Lec, was again 100% higher than the previous highest CSUF gain of 0.22. Though the post-test FCI scores for the Spring '99 modeling class were significantly higher than the Fall '98 class, the Spring '99 students had higher pretest scores, so the gains end up the same. Note the wide standard deviations (error bars) on the T2 lecture section, corresponding to students with negative gains. No students from the modeling lecture attained a negative gain. F&M = Force and Motion Exam*[18].

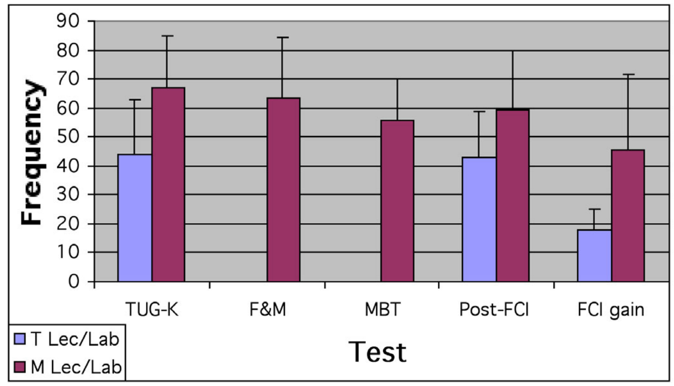

Fig. 3. *UNE Fall '98 and Fall '99: The traditional lecture and lab sequence was undertaken in the fall of '98 along with the FCI and TUG-K diagnostic exams (N = 72). JV taught the modeling sequence in the fall of '99 and all diagnostic assessments were used (N = 88). Again, on two identical diagnostic exams the modeling students appeared to be one standard deviation ahead of their traditional instruction peers and had more than twice the FCI gain compared to their traditional lecture peers.*

sponsible for lab instructor training and monitoring lab activities. The lab instructors consisted of three masters candidates, one high school physics teacher and two CSUF faculty members. None of the instructors had any prior modeling experience. All students undertook the modeling lab sequence and the two traditional lecture instructors were kept abreast of the lab content. The results from the diagnostic exams are summarized in Figure 2.

UNE:

JV was able to repeat the study in the fall of '99 in a similar undergraduate setting at the University of New England (UNE) with the assistance of coauthor PB. The opportunity to make this comparison was fortuitous, the result of a family decision to return to their New England roots. Prior to JV's arrival, UNE had a single lecture/lab instructor and used a commercially published lab manual for five to six lab sections/semester, each with up to 18 students. Their lab equipment (circa 1970s) and facilities lacked computer support. PB had taught in the fall of '98 and administered the TUG&K and FCI to his students to provide a baseline comparison for this study. JV started as the full time physics instructor at UNE in the fall of '99. He taught all lecture sections, three lab sections, and trained two lab instructors to cover the remaining labs in the modeling style. Four mechanics diagnostic assessments were administered and are summarized in Figure 3.

At both CSUF and UNE we encouraged earnest test taking by including the assessments as part of each student's grade.[19] All instructors in this study were careful not to "teach to the test", and all instructors were required to take the assessments. The integrity of the tests was maintained by creating different versions of the quizzes and taking the quizzes on the same day. Answer keys were never posted and the assessments were only available for student viewing during JV's office-hours.

CSUF Results:

Comparison of the Fall '98 test scores (Figure 1) indicated students in JV's class enjoyed a half standard deviation edge over the traditional lecture students on concept-based exams. This edge evaporated when quantitative exams were used. This result is consistent with other studies comparing traditional and interactive engagement strategies[20]. The FCI "Normalized Gain", for traditional lecture and lab yielded a modest 18% improvement (gain = 0.26) over the previous high CSUF gain of 0.22. Students taking the modeling lecture and traditional lab averaged a 32% improvement (gain = 0.29). The students who took both the modeling lecture and laboratory class averaged a 100% improvement (gain = 0.44)! The modeling lecture and lab students had graduated from the lowest to medium gain categories on the Hake Plot[9]. The modeling class scored significantly better (one standard deviation higher) on all standardized assessments when the comparison was repeated in the spring of 1999 as well (Figure 2). Modeling students again enjoyed 100% higher FCI gains over the traditional lecture students. It is important to note that modeling instruction students did no worse on quantitative exams than traditional lecture, and had substantially improved conceptual physics comprehension. Additionally JV was intentionally relieved from lab instruction and trained the laboratory instructors only. This act was undertaken to ensure that the comparison reflected the instructional process only and not a measure of a single teacher's style. Note that the traditional lecture students enjoyed higher gains than in the previous semester, we believe in part due to employing modeling instruction in all the labs!

UNE Results:

JV wanted to know if comparable gains could be achieved from a similar student population at UNE. He was concerned that the improved test results at CSUF might be an artifact of a self-selected body of diligent students. This concern was based on reliable information that JV's class at CSUF was developing a reputation of being "hard" (translated as challenging). The irony of this reputation was that the curriculum was adapted from a high school lab and exercise book. A comparison of traditional versus modeling approaches of introductory physics instruction at UNE achieved almost identical results to CSUF, including a 100% improvement in FCI gain from the modeling students. The students participating in modeling instruction also achieved substantially higher scores on the standardized tests compared to traditional lecture students (Figure 3).

Lab Instructor Training:

Of the 13 lab instructors receiving experiential training in the modeling approach at both CSUF and UNE, eight have adopted modeling instruction in their classrooms. These instructors included two professors, two graduate students, and four high school instructors. Not all of the lab instructors were convinced by the modeling approach to instruction. One skeptical university professor said:

> "I was very glad to have been involved in the modeling approach since it made me aware of other teach modes and/or techniques compared to the standard lecture/lab format. It was an introduction to the heavy debate on teaching methods in physics that are current now. However, I use almost none of the techniques from the modeling instruction in my current teaching. Part of this has to do with the fact that I'm teaching upper division courses (the advanced undergraduate E&M for example). From my limited introduction to modeling I don't see how it's possible to run advanced courses with the modeling technique. If I were teaching one of the lower division courses for which the modeling technique is more developed I'm still not sure I'd teach it in the modeling way. The reason is that modeling doesn't fit in with the way I like to teach. I was never "comfortable" using modeling. On the other hand I've spoken to other successful modeling advocates and I think they are very positive on modeling because it seems to fit in with their teaching style. Even though I'm not using any of the modeling techniques in my present teaching I think that exposure to modeling was a good thing in that it got me to think harder about what will work for my own teaching."

Four former instructors mentioned that modeling made a positive impact on how they communicated with the students, and by extension, how they communicate today in their nonacademic positions. One of these former instructors put it this way:

> "... it is a little hard for me to tell what exposure to modeling instruction made on my teaching since I am not a full time teacher. I think, however, that using a modeling approach in the classes that I had at UNE allowed me to find at least one path, one train of thought to get the subject matter into the heads of the students. If they didn't understand the subject one way they might grasp it another. If I could find that one path then I could make sense to them, of the entire method, which generally resulted in the student learning the model."

However, the majority of the lab instructors are now enthusiastic converts to modeling instruction. One former high school instructor said this of modeling:

> "Learning to use modeling instruction has profoundly changed my teaching of high school general science and physics. I would not yet consider myself a master of modeling techniques, but every year I am incorporating more of the pedagogy into my instructional practice. It has made a tremendous difference. My classes are more student-centered. My students are more comfortable articulating their thinking processes. They are constructing more of their own knowledge. They are more engaged and less bored. Using modeling has brought very positive recognition to my teaching. In the year 2000 I was given a "Teacher of the Year" award by a committee of other teachers in my district. They observed a modeling lesson and were completely blown away by what my freshman science students were doing. In fact, through most of the lesson many of them thought I was teaching a senior level physics class. They were shocked when I told them they were observing general science freshman giving whiteboard presentations. Many teachers in my department and elsewhere in my district are now using whiteboards with there students. Modeling was no "flash-in-the-pan" for my teaching. Its impact continues to improve my own instruction and is influencing the instruction of other teachers as well."

Discussion:

The positive gains and mostly positive response from instructors need to be placed into context with the overall objective of assisting our students at constructing physics knowledge based on hands-on guided inquiry. Many students will simply not buy into the process, especially if the course is a non-major requirement. Socratic dialog can be a very frustrating experience for students successful in the art of memorization and regurgitation. Some "A-students" from both CSUF and UNE were indignant, some even outraged, about scoring at the mean on conceptual assessments and quantitative reasoning exams after modeling instruction.

Modeling instruction had other costs as well. Three will mentioned: lab instructor training, grading, and depth versus breadth. Because the modeling instructor provides guided inquiry to their charges, they must be fully conversant in the content and alternative conceptions. At CSUF the lab instructors ranged from graduate students through professors. At UNE, with no graduate program, the lab instructors all held adjunct status and had at least a masters degree. All lab instructors took the same assessments administered to the students. Out of ten different instructors, four (three professors and one high school teacher) obtained perfect pretest scores on the assessments. The remaining instructors scored in the 40-80% range (including two Ph.D. physicists). Post-test scores for the instructors improved to an average of 85%. Unfortunately this implies that some misconceptions were probably being perpetuated. Lab instructor expertise and training is essential. This is a time consuming proposition and can be an expensive for schools with few resources. For example, after JV's departure from CSUF to UNE the lack of a faculty proponent for modeling instruction resulted in a return to the traditional confirmation lab format.

Grading:

In JV's hands the traditional lab report was a learning failure at the college level. Copying of a lab partner's results/analysis was par for the course. Reports handed in a week after lab were no more polished than those passed in immediately after lab. Lab grade averages were always high, in the 95% range. Student comprehension of models varied widely. Physical representations developed in lab are so important for effective deployment of the mathematical models JV needed to find a better learning tool. He has since swapped the graded lab report for weekly half hour lab quizzes. The quiz content focused on review and application of the previous week's lab results obtained through class consensus. The importance of the latter cannot be understated. Class consensus allowed his students to take ownership of the knowledge they were constructing. The weekly quizzes also provided an important incentive to keep the students abreast of the models.

Depth vs. Breadth:

After this study was completed JV had the luxury of abandoning all pretense of covering the traditional first semester general physics content at UNE, as there were no articulation restrictions. JV concentrated on depth of conceptual comprehension, covering only mechanics in the first semester. Students' standardized assessments have been steadily improving. A legitimate concern raised by this emphasis is that improvement on mechanics assessments is to be expected from a reduction of content. JV believes this concern is unfounded for two reasons. His students spend the extra time developing process and communication skills, not merely more exposure to demonstrations or similar problems. His students communicate their models through formative whiteboard assessments, in class peer instruction, and laboratory deployment activities.

The outcomes from this study at two universities indicate that modeling instruction significantly improved student comprehension in mechanics, without expense of content, based on established standardized assessments. Importantly, this improvement appeared to be independent of student demographics, class size, or the instructor. Instructional training and use of the modeling approach appeared to have the greatest influence on student learning. Lastly, it was possible to provide lab instructors with an experiential learning environment to learn and "do" modeling instruction simultaneously.

Acknowledgments:

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The Secondary School Enhancement Program in Physics at Kenyon College

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This is a report on an intensive summer program at Kenyon College for high school teachers funded during the decade of the nineteen nineties by the Howard Hughes Medical Institutes (HHMI). The intensity of the work and the technology of the program were its distinguishing characteristics. Let me tell you its story.

Organizing the Program:

Kenyon College is a purely liberal arts college with no tradition of teacher preparation. We have considerable strength in physics, with five faculty members and seven to eight majors graduating each year. Some of our physics graduates go on to teach at the secondary level, but almost all of them are in the independent schools. There was no local expertise for organizing and setting goals for the Howard Hughes program.

Therefore, I called on four experienced high school physics teachers in the summer of 1988 to help define the program. Mark Carle of University School in Cleveland was a former president of the Ohio Section of the American Association of Physics Teachers, and my colleague in a joint physics course taught at his school.[1] Judith Doyle was the physics teacher at Newark High School in Newark Ohio. She had a Ph.D. in chemistry, and was both an experienced teacher and the leader of many workshops for high school science teachers. William Reitz, now at Hoover High School in North Canton, Ohio, former Ohio Section president, was an expert in the use of computers in the laboratory, and an ace demonstrator. Many of us have seen him with Gene Easter at AAPT meetings, doing demonstrations in their beanies with propellers on top! Richard Zitto, now at Youngstown State University, but then at Boardman High School in Ohio, was a convener of the Youngstown Area Physics Alliance, and a third former president of the Ohio Section.

This group knew the nuances of teaching physics in the high schools that were not apparent to me. We met for several days, and produced the following operating principles for the program:

1. We would have only ten teachers for a four- week summer session, thus allowing us to work closely with them as individuals.

2. The teachers would be awarded four hours of graduate credit.

3. We would provide room and board, travel expenses, and a stipend of $1000 for the four weeks.

4. In general, the mornings would be devoted to lecture, demonstration and discussion, and the afternoons to experiment and construction. I would give the lectures, and my four colleagues, each of whom came for one week, would oversee the afternoon program.

5. The working assumption was that the teachers were experienced in course and classroom management, but needed some help to bring their courses up to standard. This resulted in the name *Secondary School Enhancement Program in Physics*. As we will see, this hypothesis required some stretching in actual practice.

We had available a sum of $100,000 from a Howard Hughes grant (plus another $12,000 from other sources) for the summers of 1989, 1990, 1991 and 1992. A second HHMI grant provided $72,000 for the summers of 1999 and 2000, when considerable technology was added to the program.

The Teachers:

Averaging over teachers is tricky, but the hypothetical typical teacher was from a small city or large town with one or two high schools, was the only physics teacher in the school, taught one or two sections of physics, had one to two years of courses in physics at a public institution, and had been teaching for ten years. There were 18 women and 43 men. Figure 1 shows teachers from West Virginia and Ohio locating their home schools.

There were, of course, some exceptions. Three physics major graduates of Kenyon and one of Denison University, with zero or little teaching experience, went through the program. The experienced high school teachers took them under the proverbial wing, and taught them the realities of secondary school teaching. In another case, one experienced teacher spent the evenings

Fig. 1. *Teachers from West Virginia and Ohio locating their home schools on maps in the lounge.*

mentoring another teacher who was coming into physics teaching after teaching music for many years.

On the other hand, we had a couple of teachers who had been full undergraduate physics majors a number of years ago, and needed a refresher course. The most extreme case was a teacher from the Sand Hills region of Nebraska who taught six classes and all of the science courses in his small high school, but had never taken a college physics course.

The teachers spent their coffee breaks during the first few days discussing their schools, telling battle stories and discussing (and damning) administration policies. Pretty soon this died away and the discussions reverted to physics and physics teaching. Few of the teachers had ever been in contact with other physics teachers for a lengthy period of time, and they had a lot of catching up to do. Many of the teachers belonged to the National Science Teachers Association, but few were members of the American Association of Physics Teachers. For the first four years I provided a one year membership to the AAPT with a subscription to *The Physics Teacher*.

However, all of them had developed interesting demonstrations, experiments and approaches to the teaching of physics. We tapped this lode of information by asking the teachers to give short talks, which they seemed eager to do after getting over the initial embarrassment of making presentations to their peers. A good example was the talk about bridge-building contests that had served as a focal point for the year at a small, rural school in northeastern Ohio. Figure 2 shows Sr. Irene Gerdeman demonstrating the proper technique for pulling a tablecloth out from under a plate.

Over the course of the programs I took hundreds of black and white 35 mm photographs, and spent many weekends developing film and printing pictures to hand out to the teachers on Monday morning. Copies of the pictures from the current year and selected pictures from previous years were pinned up on a large bulletin board outside of the classroom that was the teacher's lounge during the summer sessions. This room held the coffee pot, back copies of *The Physics Teacher*, and copies of the lab handouts and other materials developed by the teachers for their own classes.

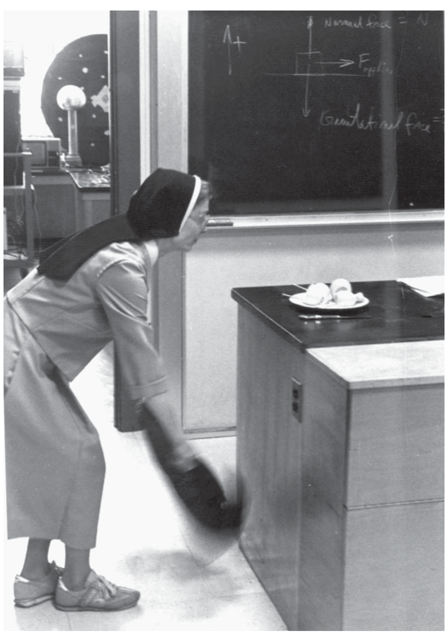

Fig. 2. *Sr. Irene Gerdeman demonstrating the proper technique of pulling a tablecloth out from under a plate.*

Fig. 3. *Dick Zitto showing his nail balancer to Sr. Irene Gerdeman.*

The Formal Lectures:

The text for the course was Franklin Miller, *College Physics*, fifth edition. This well-respected text, on the algebra-based level, was chosen because of the style of its writing. At Kenyon we have found that some students taking the calculus-level course borrow copies of Miller because it is so well written. In some years regular homework problems were assigned and discussed in class the next day.

The overall schedule for the year 2000 course is given in Table I. We decided to start with mechanics because the basic topics were familiar, allowing us to bring in new treatments with little pain. For example, I discussed a new analytical method by Zebrowski[2] of deriving the equation for centripetal acceleration. When discussing kinematics, there was a good deal of emphasis placed on learning the various graphical signatures of uniform and uniformly accelerated motion. At this point in the course I often stopped to ask how the participants taught a particular topic, and this usually led to useful discussions. We noticed that many of the teachers spent enormous amounts of time on mechanics in their own classes, teaching and reteaching it until the students got it right.

Although the structure and pace of the lectures was that of a college-level course, it was made clear that we did not think that the secondary school course should necessarily follow the lead of the college course. Indeed, we touched a number of times on the differences of the two courses, with the high school course looking at phenomena and developing techniques for describing them.

A certain amount of history of science crept into the lectures, based on my own interests. Unlike undergraduate students, who want you to give them the answers to the questions on the MCAT exams, the teachers quite liked this material, and enjoyed a lecture on the history of photography that had a good deal of optics concealed in it.

Certain topics were taught that were unlikely to be used directly in the high school physics course. An example was the Bohr model of the atom, starting with Bohr's postulates and ending with the equation for the wavelength of the spectral lines for hydrogen. Quite a number of the teachers told me that they had never seen this worked through, even though they taught the Bohr atom in their chemistry course (most of them also taught chemistry).

Accompanying the lectures were many demonstrations, using simple apparatus and human kinetics whenever possible. Dick Zitto (Fig. 3) had an engaging set of center of mass demonstrations, and I did realistic mimings of a weight lifter and a tightrope walker in action. We welcomed demonstrations brought in by the teachers, and used these as springboards for discussions of how to use demonstrations in the classroom. In some years we gave the teachers copies of *Demonstration Experiments in Physics* by George Freier[3] and discussed experiments from the book.

The one thing that the teachers wanted nothing of was formal education material. Our one attempt to get an expert to talk about assessment was unsuccessful; the material was fine, but the teachers wanted physics, not education. We also met defeat on the subject of programming in BASIC; the staff thought that this was a useful exercise and the participants did not.

On the last day Mark Carle gave a splendid lecture on quantum ideas that served to tie together the ideas we had talked about for a month. Wisely, I planned nothing after his presentation.

Experiments:

As soon as a piece of apparatus was built, it was used in an experiment, and the teachers were asked to write laboratory notes for it in language that was appropriate for their students. These notes were then distributed to the group. The idea was that the hard-worked teachers should be able to put into use at once a piece of apparatus that they built, and with their own laboratory notes, thus breaking the cycle of "I don't have time to find/set up the apparatus and find/write the laboratory notes" that is a real problem for many of them.

For the first four years we designed a number of experiments around the use of Apple II+ computers, mostly using Vernier Software for the control of photogates using the Precision Timer system. Vernier also supplied the kits (at cost) for the photogate systems that the teachers put together. During the course of the program we taught a lot of people how to solder an electrical connection! We also used the Vernier Software Ray Tracking program when studying optics.

In the last two years of the program we turned away from the use of the computer for taking data, and instead turned to the video camera and stopped-image playback of the taped phenomena. Figure 4 shows a group of teachers using several monochrome computer monitors connected in parallel to the output of a VCR elsewhere.

We gave away a certain amount of computer apparatus. In 1999 each teacher got a 486 computer that had been phased out of Kenyon programs. These machines were dreadfully slow, but were just right for data analysis using the PHYSFIT curve-fitting program that we had developed at Kenyon.[5] In earlier years, I was able to collect and pass on several Apple II+ computers, again for data analysis.

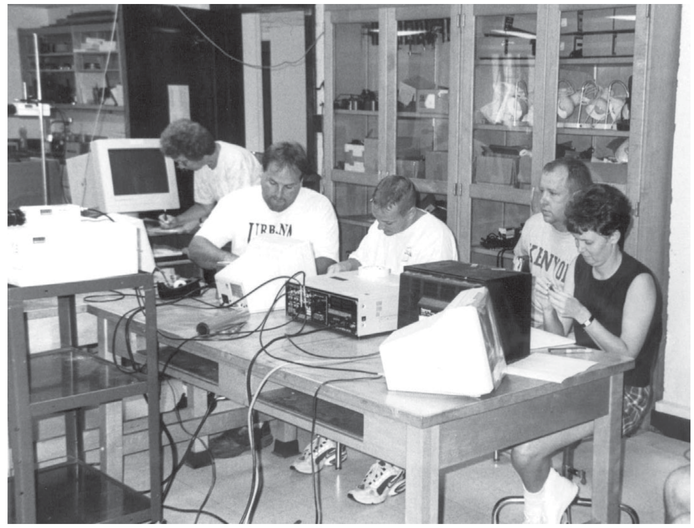

Fig. 4. *A group of teachers using several monochrome computer monitors connected in parallel to the output of a VCR to analyze motion.*

At one point, I realized that although the teachers could set up problems on the blackboard with series and parallel direct current circuits, they were not skilled at setting up the actual circuits. Therefore, we added an exploratory experiment to give them experience in such topics as "where do I put the ammeter in the circuits" that their students also have trouble with. This experiment then made it back into the set of introductory laboratory experiments at Kenyon, from which it had been removed a number of years before because we thought that it was too simple. There were several experiments that showed phenomena on a sophisticated level. Most of these were designed to give the teachers some background in modern physics, including the Millikan oil drop experiment to measure the charge on the electron, the charge to mass ratio of the electron and the photoelectric effect. Kenyon has a 5 curie neutron source, and we irradiated silver foils and made a videotape of the front of a Geiger counter (along with a clock) so that the half life of the activated silver (about 2.3 minutes) could be found. The teachers took home this tape so that students could do, at least vicariously, an experiment rarely done even by college undergraduates. This tape also included phenomena to be investigated later using the stop-action function of the VCR.

A very popular experiment in the last week of the course was the production of a single beam hologram; the common comment was that it looked so hard and was actually so easy. We did not leave this only as an experiment, however – the teachers also had a lecture by Mark Carle on the theory of the hologram. Another popular experiment was the use of a century-old 5"x7" view camera to make negatives on photographic paper instead of film, which were then used to produce positives by contact printing[6].

Judy Doyle was good at presenting AAPT workshops, and we included three of them in the program: electrostatics, data acquisition with programmable calculators and student confidence in physics. The latter had me a bit nervous, as it included a video of really terrible examples of teaching; I kept wondering if I had ever done anything quite that bad. The teachers caught hold of the ideas, and always had a good discussion of practical teaching techniques. Figure 5 shows Judy demonstrating the fine points of programmable calculator use.

During fine evenings my colleague, Paula Turner, had viewing sessions at the Franklin Miller Observatory on the Kenyon Campus through a fourteen inch telescope.

Construction of Apparatus:

For many teachers the construction of apparatus was the high point of the course. We recognized that most teachers were overburdened with preparations and classes, and had little time or experience to make apparatus. On the other hand, few of them had budgets large enough to buy apparatus, even in groups of one.

Fig. 5. *Carrie Baker and Steve Sparks being shown the fine points of programmable calculator use by Judy Doyle.*

Most of the apparatus we built was for demonstrating and observing the phenomena of mechanics. The two large projects that drew the most attention were the Giant Air Pucks and the Air Tracks. In Figure 6, Kathryn Cole and her hovercraft formed a nearly isolated system that reacted to the inversion of a spinning bicycle-wheel gyroscope[7]. Assembly-line techniques were used to cut out the disks, sand the edges, fasten on the baggy bottom sheet (held in the middle with a big thin plywood washer) and cut the holes in them. Bill Reitz told us about the air pucks in 1988, but clearly they have been in use before that time. For many teachers, male and female, this was the first time they had used hand and power tools.

The air track was the Woodrow Wilson style, based on a design used in summer programs at Princeton. It is a six-foot length of square plastic down-spouting with #60 holes drilled on

Mon 6/26	Check in. Class and lab on 1-D kinematics using video systems
Tue 6/27	Class and lab on 2-D kinematics using video and film systems
Wed 6/28	Class on linear dynamics & energy. Air track construction
Thu 6/29	Class and experiments on linear dynamics & energy. Make air pucks
Fri 6/30	Class and experiment on momentum, center of mass, energy
Mon 7/3	Class and experiment on rotational kinematics and dynamics
Tue 7/4	Class on rotational dynamics. Parade. Make ultrasonic apparatus
Wed 7/5	Class and experiment on SHM and oscillations. Speed of sound expt
Thu 7/6	Class and experiment on waves. Ultrasonic interferometers
Fri 7/7	Class on acoustics and music.
Mon 7/10	Classes on electrostatics and electrostatics workshop
Tue 7/11	Class and experiments on direct current experiments
Wed 7/12	Electric fields and electron ballistics. Exponential decay experiments
Thu 7/13	Class on magnetic fields. Student Confidence Workshop
Fri 7/14	Class on magnetic fields. Charge and mass of the electron
Mon 7/17	Class and experiment with optics. RC decay with oscilloscope
Tue 7/18	Class and experiment with optics
Wed 7/19	Class and experiment on wave optics. Decay of radioactive silver
Thu 7/20	Class and experiment on the Bohr atom. Holography
Fri 7/21	Class on modern physics and applied optics

Table 1. *This is the schedule for the program held during June and July 2000. Note the "Parade" on July 4th when we all went to see the Gambier Fourth of July Parade, including a performance by the Gambier Mime School.*

Fig. 6. *Kathryn Cole and her hovercraft formed a nearly isolated system that reacted to the inversion of a spinning bicycle-wheel gyroscope.*[6]

both upper sides down its length. The pucks were lengths of aluminum angle. Again, mass-production techniques were used to build the tracks efficiently

One of the most popular projects was the set of two seemingly-identical moment of inertia batons that each teacher built. These were made of plastic pipe, with one baton evenly loaded at the ends and the other loaded at the center. When grasped at the center and rotated, their response was dramatically different.

Another interesting construction project, at least among the Ohioans, was gluing a road map of Ohio onto a foam-board backing, cutting it out, and finding the center of mass of the state (Centerburg!) by suspending the state from Toledo, Youngstown and Cincinnati.

Technology:

The budget was increased considerably in the last two years of the program to allow the introduction of more technology. The teachers were supplied with a 20 MHz dual beam oscilloscope, a function generator (sine, square, sawtooth waves) with a digital readout, a He-Ne laser, a low voltage power supply and a reasonably good multimeter. They built sets of three ultrasonic transducers operating at 40 KHz, and learned to do a number of experiments with them, using the function generator as a driver and the oscilloscope as an output device.[8] I included a thorough discussion of one of my favorite topics, Lissajous figures, and the students learned how to create them with the oscilloscope and function generator.

The function generator was used to generate square waves, which were then used to charge a capacitor, with the resulting decay being observed on an oscilloscope. This experiment served as an introduction to the mathematics of exponential decay that was encountered later in the silver decay experiment.

Successes:

The course had several surprising outcomes. One teacher from the first year brought his knowledge of physics up to the point that he is now teaching a Kenyon-sponsored, non-calculus-level physics course in his school in the Cleveland area. The students get Kenyon transfer credit, and also do quite well in the Advanced Placement examinations. A second teacher, originally trained in biology, used the experience from the HHMI program to write a successful NSF-sponsored proposal to teach science to elementary and middle school teachers in her medium-sized Ohio city over a four year span in the mid-nineties. And, she hired Greenslade and Zitto to teach the physics segment of the program! Another teacher from the far Midwest started a university summer course based on the HHMI model.

An unexpected success was the marriage of two of the participants two years after the summer program. I felt like a fairy godfather when I went to the wedding.

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JPTEO

Clinical experiences for high school physics teacher candidates

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Clinical experiences for teacher candidates are designed to bridge the gap between educational theory and practice. They should provide students with a chance to apply their knowledge of physics, adolescent psychology, and pedagogical theory to physics teaching. Several clinical experience activities will be offered in this column regularly as a means of improving novice teacher practice. Readers are encouraged to send in examples of their own clinical experiences for publication in this column.

Classroom Management Styles

There are a number of management styles that both parents and teachers exhibit. There have been a number of psychological studies of parenting styles that naturally would appear to extend to classroom management styles for teachers. I hypothesize that such a relationship exists. Classroom management styles of teachers can be characterized along two dimensions: type of control exercised over students, and degree of involvement of teachers with students. The extremes of these two dimensions allow teacher management of students to be readily identified. Control can run the gambit from high in which teachers explicitly "lay down the law" and very strictly enforce it, to low in which the teachers have no rules and no expectations for their students. Involvement, likewise, can range from high to low. High involvement is characteristic of teachers who have high regard for students, likes students, enjoy being around students, and want to see students do their best. On the other hand, low involvement shows a real lack of both regard and concern for students. The classroom management styles of teachers can be readily identified on the basis of both degree of control and level of involvement. The nature of each management style can be identified from the chart below.

Teacher **Involvement** **Control**	**High**	**Low**
High	*Authoritative*	*Authoritarian*
Low	*Indulgent*	*Permissive*

According to Baumrind[1], the authoritative style encourages independence, is warm and nurturing, control occurs along with explanation, and adolescents are permitted to express their views. The authoritarian style tends to be punitive and restrictive, and students have neither a say in their management, nor are they seen to need explanations. The permissive style is characterized by a lack of involvement, the environment is non-punitive, there are few demands on students, and there is a lot of freedom. The indulgent style presents an environment where there are no demands on the student of any sort, and the students are actively supported in their efforts to seek their own ends using any reasonable means. These four styles represent extremes, and most teachers demonstrate a certain degree of inconsistency in their use of styles. Research has shown that the type of management style results in characteristic behaviors. The authoritative style helps to produce students who are socially competent and responsible. The authoritarian style helps to produce students who are ineffective at social interaction, and somewhat inactive. Both indulgent and permissive styles help to produce students that are immature, show poor self-restraint, and who exhibit poor leadership skills. What sort of classroom management style will you exhibit once you begin teaching? Which style you demonstrate is most consistent with your upbringing, and degree and type of preparation as a teacher. Which style is most consistent with your personality? Would you feel comfortable with this style? High might you work to change it if you don't like what you see?

Reference:

1. Baumrind, D. (1971). Current patterns of parental authority. *Developmental Psychology Monographs, 4*(1).

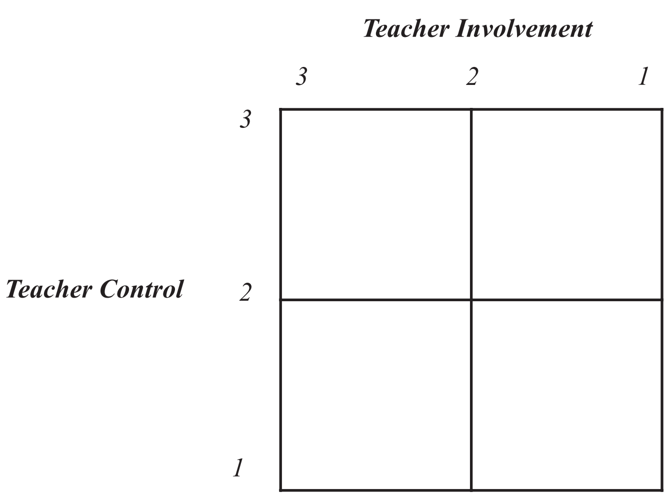
Built Environment Checklist

In 1991, the AAAS published *Barrier F R E E in Brief,* a set of books containing very useful information for those who work with students with disabilities. Two key sets of information are worth noting: access in both word and deed. When it comes to language, the following points should be kept in mind: put people first, not their disabilities; avoid identifying a group of people as a disability category; describe mobility aids or other technology as useful devices to the individuals rather than extensions of themselves; avoid emotional or degrading terms; remember to distinguish between disabilities and handicaps and the non-disabled and "normal." There are other courtesies that should be extended to those with disabilities: always speak to a person with a disability directly, even if an interpreter is present; when speaking with someone in a wheelchair for more than a few minutes, sit down; when talking to someone with a hearing impairment, look directly at the person and speak clearly. Never shout; use notes; to gain the attention of someone who is deaf, wave hand or tap on shoulder; assist those with visual impairments to take your arm, after identifying yourself; don't make assumptions about person or disability; ask before you help, and relax. The Americans with Disabilities Act ensures those with disabilities equal access to education. As such, schools must remain barrier free. On the following page you will find a Built Environment Checklist that can be used to determine just how accessible a school site is for its students with disabilities.

Classroom Management Style Assessment

Observe a teacher's classroom management style in an attempt to determine what sort of practice is employed — authoritative, authoritarian, indulgent, permissive, or mixed — as characterized by Baumrind (1971). Examine behaviors as they relate to student control and student involvement. Based upon your assessments in these areas and the modified Baumrind matrix, determine classroom management style. Place a "3" in the box if this aspect is observed to a high degree, a "2" if observed to a moderate degree, and a "1" if observed to a low degree. Average your scores in each area (control and involvement). Plot the averages for teacher control of students and teacher involvement with students on the grid near below. Compare this result with the information found on the previous page.

TEACHER CONTROL OF STUDENTS:	Score	Average
Classroom rules (score 3 if highly detailed, 2 if moderately detailed, score 1 if only states basic principles)		
Enforcement of rules (score 3 if teacher complains about minutia, score 2 if teacher remarks about only important matters, score 1 if doesn't care).		
Use of punishment (score 3 if frequent, score 2 if infrequent, score 1 if not observed.)		
Expression of student opinions (score 3 if frequent, score 2 if infrequent, score 1 if never)		
Calculate Average		
TEACHER INVOLVEMENT WITH STUDENTS.	Score	Average
Teacher regard for students (score 3 if high, score 2 if moderate, score 1 if teacher appears not to care)		
Affection for students (score 3 if teacher appears to like students, score 2 if teacher appears neutral, score 1 if teacher appears to dislike students)		
Expressions of high expectations for students (score 3 if frequent, score 2 if infrequent, score 1 if teacher appears not to care)		
Encouraging student independence (score 3 if teacher stresses self-reliance and responsibility, score 2 if significant guidance, score 1 if teacher micromanages)		
Calculate Average		



Teacher Management Style: ____________________________

Built Environment Checklist

	YES	NO
STUDENT PARKING:		
Are there well-marked, handicap-accessible (16' wide) parking spaces near an accessible entrance?		
Is there a sufficient number of accessible parking spaces available?		
Is there a wheelchair-accessible pathway leading from the parking area to an accessible entrance?		
OUTDOOR ACCESS:		
Are there curb cuts from the sidewalk to the street and parking lot?		
Do ramps exceed an 8% slope or a 1/12 rise-to-run ratio?		
Are accessible entrances to the building at least 32 inches wide?		
Do the accessible doors have a door-opening assist mechanism?		
INSIDE THE BUILDING:		
Are doorway thresholds less than 1/2 inch in height?		
Are doorways at least 32 inches wide? (clear width)		
Do ramps exceed an 8% slope or a 1/12 rise-to-run ratio?		
Are there protruding objects from the walls that might pose a danger to students who are visually impaired? (protrusions more than 4 inches)		
Are there student-accessible elevators?		
Are all elevator buttons marked in Braille numbers or raised notation?		
Do the elevators have auditory and visual indicators for floors?		
Where telephone are available for students, are lower public telephones provided for persons who use wheelchairs?		
Are volume-control telephones available for people who need them?		
Are telecommunication devices for the deaf (TDDs) available anywhere?		
Can water fountains be used by someone sitting in a wheelchair?		
RESTROOMS:		
Are there wheelchair-accessible restrooms near the classroom or laboratory?		
Are wheelchair-accessible restrooms available on each floor?		
Are grab bars placed a maximum of 1-1/2 inch from the walls of stalls?		
Are sinks, soap and towel dispensers and other accessories within easy reach of someone who is short-statured or sitting in a wheelchair?		
CLASSROOMS:		
Are students with a disability able to adjust seating so as to make the best accommodation?		
Are assistive listening devices available to students in need?		
Are visual aids available as needed?		
Are available TVs capable of showing closed captioning?		
LABS:		
Are the isles at least 42 to 48 inches wide?		
Are workplaces available as needed that have:		
controls for safety and utility equipment that are easy to reach and to use by students with disabilities?		
faucets and valves with lever handles, push-plate switches, and large push buttons for those with limited strength/dexterity?		
work surfaces no higher than 30 inches from the floor for use by those in wheel chairs?		
cleared spaces under work surfaces with free space at least 29 inches high, 36 inches wide, and 20 inches deep for leg room?		
work tables for equipment such as microscopes can also be lowered for people in wheelchairs or with short stature?		

