PET
Physics and
Everyday Thinking

Physics and Everyday Thinking (PET)

Final Evaluation Report

Based on Data Collected from 2001 – 2007

Prepared by the External Evaluation Team
Science and Mathematics Program Improvement (SAMPI)
Mallinson Institute for Science Education
Western Michigan University

Winter 2008

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FINAL EXTERNAL EVALUATION REPORT

Physics and Everyday Thinking (*PET*)

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About this Document

This document is a summative external evaluation report of the *Physics and Everyday Thinking* (*PET*) materials development and dissemination project. It includes a summary of findings from the 6-year evaluation effort, including a discussion of the project and its activities; findings from college student and in-service teacher pre/post content tests; interviews with pilot-test and field-test faculty, pre/post in-service teacher surveys; end-of-PD session evaluations; in-service teacher interviews; and follow-up surveys of *PET* curriculum users. A variety of reports based on specific data collection have been prepared over the course of the project and are available from the project director.

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> **"*PET* students are involved in their own learning, active all the time, reflecting, discusses ideas."**
>
> **"Students advanced over the semester . . . they were able to give up what they thought they knew in the face of new data."**
>
> **"Students see how scientists frame things, gain appreciation of how science functions as a whole."**

Comments from Field Test Faculty
following implementation of *PET* in their classrooms

INTRODUCTION

Through a grant from the National Science Foundation, the Center for Research in Mathematics and Science Education (CRMSE) at San Diego State University, under the direction of Dr. Fred Goldberg, has developed *Physics and Everyday Thinking* (*PET*), a physics curriculum and support materials for use in undergraduate courses for prospective teachers and in-service teacher workshops. Details about the program can be founded at http://PETproject.sdsu.edu.

This document is a final evaluation report for *PET* for the period, 2001-2007. It was prepared by the external evaluation team for project staff and funding agencies. In addition to discussion of project activities, it presents findings from the evaluation, along with evaluator comments.

Organization of the Report. This report is organized into seven major sections: 1) Background; 2) Evaluation Activities; 3) Summary of Findings and Evaluator Comments; 4) Evaluation Findings: Effects on College Students; 5) Evaluation Findings: College Courses/Faculty; 6) Evaluation Findings: In-service Elementary Teachers, and 7) Evaluation Findings: *PET* Users.

BACKGROUND

Physics and Everyday Thinking (PET) is a curriculum and associated instructional materials, along with web-based professional development support materials, designed for use in physical science content courses for prospective elementary teachers and other undergraduate non-majors, and in-service teacher workshops. The *PET* development project, funded by the National Science Foundation, has been headquartered at San Diego State University, where project activities began in 2001. It has resulted in a comprehensive set of printed and on-line college-level course materials, corresponding materials for use in elementary classrooms, as well as professional development support materials for college instructors on the use of the *PET* curriculum.

PET was developed by a team of science educators, including Dr. Fred Goldberg of San Diego State University (Principal Investigator), Dr. Steve Robinson of Tennessee Technological University and Dr. Valerie Otero of Colorado State University (Co-Principal Investigators), and several graduate students and support staff. On completion of the first draft of *PET* materials, five additional collaborators from institutions of higher education across the country pilot-tested materials and provided feedback to the core development team. Subsequently, a cadre of 15 physics instructors from 2- and 4-year colleges, were trained on the use of *PET* and then field-tested the materials in a variety of course settings.

PET was partially adapted from earlier work done by Dr. Goldberg and colleagues—*Constructing Physics Understanding (CPU)* and *Constructing Ideas in Physical Science (CIPS)*—constructivist-based physics programs for use at secondary school and college levels. *PET* has four primary goals:

- *Physics Content:* To help students develop a deep understanding of a set of physics ideas
- *Nature of Science:* To help students practice the scientific process and understand how knowledge is developed within the scientific community
- *Elementary Students' Ideas:* To help students analyze and appreciate the thinking of elementary students while they engage in scientific inquiry, and to make connections between children's learning and their own learning of physics
- *Learning About Learning:* To help students become more aware of how their own physics ideas change and develop over time and how the structure of the learning environment and curriculum facilitate these changes

The *PET* curriculum is organized into seven "cycles of learning" with a common theme of *interactions.* According to the developers, "Students learn to describe interactions in terms of either energy or forces." The cycles include: 1) Interactions and Motion, 2) Interactions and Forces, 3) Interactions and Fields, 4) Model for Magnetism, 5) Electric Circuit and Electromagnetic Interactions, 6) Light, Heat Conduction and Infrared Interactions, and 7) Interactions and Conservation.

Generally readily available physical science apparatus and MBL motion sensors are used to conduct hands-on activities in the various cycles. Specially designed computer simulations are available to instructors and students for both classroom and Internet homework assignments. The Elementary Students' Ideas (ESI) component has in-class and homework activities that provide students with opportunities to analyze video segments of elementary students as they work through physics activities. A comprehensive web-based teacher guide provides a variety of materials to support instructors in implementing the *PET* curriculum.

EVALUATION ACTIVITIES

The purpose of the external evaluation was to 1) provide evaluative information to *PET* developers to improve curriculum materials and 2) determine effects of the *PET*-based programs on participants. The primary audience for the evaluative information has been the developers and field test colleagues.

The external evaluation of *Physics and Everyday Thinking (PET)* has been conducted by Science and Mathematics Program Improvement (SAMPI), Mallinson Institute for Science Education at Western Michigan University. Dr. Mark Jenness, Director of SAMPI, has served as lead evaluator for the project. More information about SAMPI can be found at www.wmich.edu/sampi/.

The evaluation has included several components, both formative and summative in nature. As the *PET* materials have been developed, evaluators have gathered feedback from many different stakeholders, including college/university faculty collaborators and field testers, college students enrolled in classes using *PET* materials, in-service teachers participating in *PET*-based workshops, and users of the published *PET* materials. Information has been collected through email and paper surveys, field testing of *PET* Jr. materials, email/telephone and on-site interviews, and observations of professional development sessions and *PET* course implementation. A pre/post course/workshop *PET*-based physical science content test (devised by the *PET* development team) has been administered in 45 different classrooms and five in-service teacher workshops. A variety of reports based on these various data collection efforts have been provided to the development team over the course of the project, including analyses of each course in which the *PET* materials were field tested. Selected reports are summarized in this report.

Types of Reports Prepared by the External Evaluation Team

What follows is a list of primary kinds of formal reports prepared by the external evaluation team over the course of the *PET* project. It should be noted that the various instruments and procedures necessary to gather the data from which the report was prepared were also created by the evaluation team.

- Email interviews of students involved in *PET* pilot class.
- End-of-training session evaluation questionnaire for pilot and field test faculty.
- Pre-summer training interviews of field test faculty.
- Follow-up email/phone interviews of pilot and field test faculty.
- Pre/post content test results from pilot and field test classes (45 total).
- End-of-*PET* class student survey—pilot test sites.
- Mini-case studies of field test faculty implementation of *PET* in their courses (2 cases).
- End-of-summer elementary teacher workshop evaluation questionnaires.
- Elementary teacher feedback based on their field test of the *PET* Jr. materials.
- Follow-up interviews of elementary teachers field testing *PET* Jr. materials.
- Compilation of responses of elementary teacher pre/post survey.
- Pre/post content tests from elementary teacher workshops.
- Compilation of responses from interviews of users of published *PET* materials.

Physics and Everyday Thinking (*PET*)

SUMMARY OF FINDINGS and EVALUATOR COMMENTS

Prepared by the External Evaluation Team
Science and Mathematics Program Improvement (SAMPI)
Mallinson Institute for Science Education
Western Michigan University

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About this Summary Report. This section of the final report presents a summary of findings and evaluator comments based on the complete summative evaluation report for *PET*. Readers are referred to the complete report for detailed findings. Both the complete and summary reports are based on evaluative data collected between 2001 and 2007.

About *Physics and Everyday Thinking* (*PET*). *PET* is a curriculum and associated instructional materials, along with web-based professional development support materials, designed for use in physical science content courses for prospective elementary teachers, other undergraduate non-majors, and in-service teacher workshops. *PET* was developed by a team of science educators, including Dr. Fred Goldberg of San Diego State University (Principal Investigator), Dr. Steve Robinson of Tennessee Technological University and Dr. Valerie Otero of Colorado State University (Co-Principal Investigators), and several graduate students and support staff. Twenty physics instructors from higher education institutions across the country field tested materials in one or more of their classes. The *PET* development project was funded by the National Science Foundation, and has been headquartered at San Diego State University, where project activities began in 2001. It has resulted in a comprehensive set of printed and on-line college-level course materials, corresponding materials for use in elementary classrooms, as well as professional development support materials for college instructors on the use of the *PET* curriculum.

External Evaluation. The external evaluation of *Physics and Everyday Thinking (PET)* has been conducted by Science and Mathematics Program Improvement (SAMPI), Mallinson Institute for Science Education at Western Michigan University. Dr. Mark Jenness, Director of SAMPI, has served as lead evaluator for the project. The purpose of the external evaluation was to 1) provide evaluative information to *PET* developers to improve curriculum materials and 2) determine effects of the *PET*-based programs on participants. The primary audience for the evaluative information has been the developers and field test colleagues. A variety of quantitative and qualitative evaluative data was collected over the course of the project.

Summary of Evaluation Findings

What follows is a brief summary of findings from the external evaluation. Readers are encouraged to review the complete evaluation report to better understand the strengths and limitations of *PET*.

Effects on College Students

Pre/Post Content Tests. Test items pertinent to the core cycles of the *PET* curriculum were created by the *PET* development team. For each of the 7 items, students were given a situation and then asked to 1) select an answer from several choices (multiple choice) and 2) then explain their choice. Tests were administered by pilot- and field-test faculty. Developers also prepared, in collaboration with the external evaluation team, a scoring rubric. External evaluators scored all tests and conducted a pre/post analysis of the data.

- Tests were administered to undergraduate students participating in *PET*-based physics or physical science courses, primarily for pre-service teachers, at the beginning and end of one-semester courses. Sites included four-year institutions and community colleges. Although most students were sophomores or juniors, their demographics were quite variable. A total of 1119 students in 45 different classes conducted by 25 different instructors at 18 different sites across the United States completed pre- and post-tests between Fall 2003 and Spring 2005.

- To determine the statistical significance of changes from pre to post, a paired t-test was done on total scores. For all sites, the change in scores from pre to post was significant at alpha <=0.01. This indicates that overall student responses to test items were significantly higher (based on the scoring rubric criteria) from pre to post.

- At one site, a simple comparison group analysis was conducted between a *PET*-based laboratory section and a more traditional lecture section covering the same materials. Students were self-selected for the two classes and came from the same student pool. Students in the *PET*-based class started out somewhat ahead of those in the traditional class (on the pre-test) and performed better than students in the traditional class on the post-test. Students in the *PET* class made significantly greater gains on the total score and on two of the 7 items.

- Among the 45 classes in which the *PET* materials were field tested, the nature of training on the *PET* materials varied. Scores from pre/post tests were analyzed to determine if there were any statistically significant differences in results based on the nature of training received by instructors. No difference was found except for one person who received no training.

- All pre/post test items required students to provide a written rationale for their answers to the questions. The qualitative aspects of student responses to test items also provided insights into the effects of the *PET*-based courses on student thinking. In many cases, the nature of the explanation (rationale) for the chosen answer was much clearer and compelling on the post-test than the pre-test.

Effects on Courses/Faculty

Faculty Beliefs About Teaching and Learning . . . and the* PET *Materials. Each of the faculty members had their own particular beliefs about the teaching and learning of physics content among undergraduates at the beginning of their experience with the *PET* materials. The nature and extent of change in these beliefs were specific to each individual. Thus, making broad generalizations about these issues based on an analysis of evaluation data is problematic. Almost any general comment has to be accompanied by many statements of exception. What follows is a discussion about faculty beliefs (in the context of implementing the *PET* materials) based on an analysis of interviews with participating faculty.

- All faculty who participated in *PET* training (referred to as Field Testers) had responsibilities at their home institutions for teaching undergraduate physics content courses that met program requirements for pre-service elementary teachers. All had a background in physics and/or physics education. Likewise, colleagues of these Field Testers who also implemented *PET* (receiving advice and coaching from the Field Testers) had responsibilities for undergraduate physics courses and background in physics and/or physics education.

- Field Test faculty participation in the training was motivated by personal interest in the *PET* program, recommendation by a colleague, recommendation by a department chair or other supervisor, or because of the reputation of the *PET* developers. One person participated because of a reassignment to physics classes specifically for pre-service elementary teachers.

- All were familiar with the ideas of constructivist approaches to learning based on their experience, review of current literature, attendance at pertinent conference sessions, or discussion with colleagues. Only a few were actually making significant use of these approaches in their current classes, although most had “experimented” with inquiry-focused activities.

- At the end of the one-week training session in Summer 2004, participants were asked to rate the effectiveness of the training in helping them understand core assumptions supporting the *PET* curriculum.
  - 81% indicated they had a very firm understanding that student learning is a social process and through social interaction students articulate and refine their ideas.
  - 75% said they had a very firm understanding that students have prior knowledge about science concepts based on life experiences as well as their interpretation of prior formal learning experiences.
  - 94% said they had a very firm understanding that difficult ideas develop over time—students are active learners who may have partial ideas at a given time—confusion and frustration may be normal parts of the learning process.
  - 88% said they had a very firm understanding that the *PET* classroom environment (norms of respect, evidence, responsibility), pedagogy, and curriculum are collectively different from those of a traditional class.

- Several Field Testers said they anticipated that students would be resistant to the student-centered nature of the *PET* curriculum. Most said that students complained about what they perceived as lack of direction by the instructor. In almost every case, however, faculty indicated that by mid-term students had adjusted to the different teaching/learning style and were much more accepting of the more constructivist approach. Even the skeptics among the Field Testers said their predictions of student resistance was probably overstated—most students did adjust as the course unfolded.

- There were differences of opinion among Field Testers about the nature and extent of the content covered in the *PET* materials, as well as some of the strategies used to teach the concepts. Most of the Field Testers had their existing “*PET*” topics and ways of teaching them, not always consistent with *PET*. Although most tried to implement *PET* as written, some did deviate from the intended curriculum.

- Most of the Field Testers had to adjust their own teaching styles, since they had not previously used a largely student-centered approach. Many found this approach invigorating, although challenging, and plan to continue using it. Others were less enthusiastic about the constructivist approach and indicated they believed students needed at least some direct teaching.

Changes in Courses. At all sites, courses were developed or modified to use the *PET* materials. For the field test effort, faculty at two sites created new courses to accommodate the *PET* program. At the other sites, the *PET* materials were substituted for the existing curriculum, integrated into/added on to the existing curriculum, or adapted to the existing program. At four field test sites, instructors added content and/or assignments to the *PET* curriculum.

- Several Field Test faculty indicated in interviews prior to their participation in the summer training session that they (and, in most cases, their colleagues or department chairs) recognized various shortcomings of current course offerings at their institutions as reflected in negative student course feedback (and student attitudes), increasingly poor student grades, and their review of the current literature on teaching of physics. Several of these faculty and others indicated they wanted to revise their courses to make them more student-centered and inquiry-focused. Training on the use of *PET* would provide them with an opportunity to explore more fully one student-centered curriculum.

- For most of the classes taught by the Field Test faculty prior to their use of *PET* materials, the focus of these courses was almost entirely on teaching physics content, with limited emphasis on how students learn. In implementing *PET*, faculty indicated that there was more focus on student learning when planning and implementing class activities. Those faculty who had taught physics content courses in the past for pre-service elementary teachers or courses with large numbers of pre-service teachers said the *PET* curriculum had many elements that allow their own college students to think about learning, as well as (through ESI activities) how elementary students learn physics concepts. There were some who were skeptical of ESI activities as a key element of a physics course, but all Field Testers did try to faithfully implement *PET* as intended. For some, using ESI was out of their teaching “comfort zone.”

- For some faculty, *PET* reaffirmed their beliefs about the need for more student-centered courses and provided materials shown to improve student learning if implemented as intended. *PET* provided them with “ammunition” as they worked with their colleagues and department chairs to make changes in current courses or to create new *PET*-based courses. For many of them, *PET* reinvigorated their courses and their teaching. Although not universal, several indicated that student interest, attendance, and grades improved in their *PET* courses.

***Strengths of* PET.** Field test faculty identified various strengths of the program. Below is a sample of their comments.

- “Curriculum is finely crafted, well put together, leads students through things, very tight coherence, straightforward, straightforward for students, too.”
- “Well integrated, excellent the way the course builds on previous material; leads them through very carefully.”
- “The students struggle through the concepts, then they figure it out; the curriculum really takes them through that process.”
- “Scientist’s Ideas [component] wrap up and allow the validation students are seeking.”
- “Got done and said, ‘Yes, we’ll definitely do that again,’ which is different from what we’ve said about everything we’ve tried in the past.”

***Limitations of* PET.** Field test faculty also identified various limitations of the program. Below is a sample of their comments.

- “It is hard for instructors to avoid validating, requires training and support.”
- “Students can be frustrated by their groups, can have groups with bad ‘chemistry’ or dysfunctional groups.”
- “Limited by lab space; can’t run as many students through the class as needed.”
- “Students complain curriculum is very repetitive; they are being asked the same thing three and four times; they see this as tedious, a waste of their time.”
- “Students lack enough classroom experience to use ESIs fully, some students don’t respond to ESIs or don’t read them carefully.”

Effects on In-Service Teachers

Using* PET *for In-Service Teacher Workshops. A total of 131 teachers participated in five workshops that used the complete *PET* curriculum (81 additional teachers participated in a short-version workshop). At the end of the workshops, teachers were asked to rate a series of procedures and activities that were used in the workshop on how useful they were in helping them understand the physical science concepts studied in the workshop on a 5-point scale, with 1 = Not useful and 5 = Very useful. The table below shows mean ratings across workshop sites.

Procedures/Activities Used in Workshop	Mean Ratings				
	Site 1	Site 2	Site 3	Site 4	Site 5
1. Knowing the Key Question to be answered by an activity or experiment	4.70	4.62	4.53	3.94	4.35
2. Conducting the experiments and other hands-on activities	5.00	5.00	5.00	4.88	4.90
3. Working in teams	4.90	4.81	4.88	4.52	4.62
4. Making claims based on evidence	4.78	4.86	4.94	4.76	4.64
5. Developing consensus ideas	4.80	4.57	4.88	4.42	4.05
6. Printed activity sheets	4.50	4.74	5.00	4.06	4.13
7. Computer-based simulator activities	4.90	4.76	5.00	4.52	4.33
8. Computer-based motion detector activities	5.00	4.81	4.94	4.73	4.56
9. ESI materials/resources and activities	4.50	4.67	4.59	3.93	4.26
10. Whole class summarizing discussions	4.20	4.76	4.88	4.21	4.44
11. Scientists' ideas	4.50	4.57	4.65	4.18	4.36
12. Sharing and discussing your initial ideas at the beginning of activities	4.40	4.90	4.59	4.00	4.51

- In follow-up interviews 8 months after their participation in the workshops, participating teachers were asked whether their beliefs about teaching and learning of science had been changed in any way. 82% responded positively; 18% said their beliefs had not changed. 44% indicated they had come to believe that hands-on, inquiry-based teaching and learning "really is better" than directed, book-based learning. 18% said that their beliefs were changed about use of questioning strategies and intentionally not giving answers.

- Asked in the follow-up interviews what they had learned about science, scientific thinking, or the processes of science, 65% responded that they had learned about the techniques and usefulness of inquiry-based teaching and learning of science, including using investigation and exploration, hands-on learning, not giving answers, the process of making predictions and searching for answers, and supporting findings with evidence. 32% said they learned about the significance of misconceptions, both students' and teachers'. 19% indicated they learned about the importance of collaboration and group work. 12% learned about the usefulness of white boards for sharing ideas and having students share what they are thinking.

In-Service Teachers: Changes in Content Knowledge. As with pre/post test scores from college classes, the statistical significance of changes from pre to post were determined for test results in the in-service teacher workshops. A paired t-test was done on total scores and individual item scores. The table below shows results of t-test on total scores. Results show that overall participant responses to test items were significantly higher (based on the scoring rubric criteria) from pre to post.

Workshop Site	Number of Participants	Pre-Test Mean	Post-Test Mean	Gain Score	Total Points Possible
AA	21	5.14	16.24	11.10*	25
BB	18	6.22	17.56	11.33*	25
CC	32	6.41	15.88	9.47*	25
DD	10	3.50	14.00	10.50*	25
EE1	81	2.68	7.70	5.02*	9**
EE2	35	8.03	17.60	9.57*	25

*Statistically significant change from pre- to post-tests (alpha <= 0.01)

** This group completed only the first three test items related to first three *PET* cycles.

Changes in Classroom Practices. Teachers were asked to complete a survey at the beginning of the summer workshop and again in Spring 2005. It was designed to gather information about their perceptions of their preparedness to teach particular science topics, preparedness to facilitate particular activities during their science lessons, use of particular instructional strategies, and frequency of student participation in particular activities during science lessons. A sample of findings is shown below. Readers are referred to the full evaluation report for details.

- *Science Topics.* Teachers were asked to rate their preparedness to teach six physical science topics related to *PET* on a 4-point scale. There was a statistically significant increase from pre to post for all topics: motion of objects, forces, magnetic interactions, light, electric circuit, and energy.

- *Classroom Activities.* Teachers were asked to rate their preparedness to facilitate six different classroom activities relevant to the *PET* approach to teaching and learning on a 4-point scale. There was a statistically significant increase from pre to post for all topics:
  - Leading a class using investigative strategies
  - Managing a class engaged in hands-on/project-based work
  - Making connections within and between science subjects
  - Making connections to real-world situations
  - Helping students take responsibility for their own learning
  - Recognizing and responding to diverse student needs

- *Science Teaching Practices.* Teachers were asked to rate how often they use eight particular strategies in their science lesson on a 5-point scale, with 1 = Never and 5 = All or almost all lessons. There was a statistically significant increase in frequency of use from pre to post for 6 out of the 8 items:
  - Introduce content through formal teacher presentations
  - Use open-ended questioning strategies
  - Require students to explain their reasoning when giving answers
  - Encourage students to communicate scientifically
  - Encourage students to explore alternative methods for solutions
  - Conduct systematic observation of student activities for the purpose of assessment

- *Student Activities.* Teachers were asked to rate how often their students took part in 20 different activities as part of their science lessons on a 5-point scale, with 1 = Never and 5 = All or almost all science lessons. There was a statistically significant increase from pre to post for seven of the twenty activities:
  - Participate in discussion with the teacher to further science understanding
  - Write reflections in a notebook or journal

- Write a description of a plan, procedure, or problem-solving process
- Take tests requiring constructed responses
- Design or implement their own investigation
- Work in cooperative learning groups
- Record, represent, and/or analyze data

There was a statistically significant decrease from pre to post for two of the twenty activities:

- Take short-answer tests
- Answer textbook/worksheet questions

Users of Published *PET* Materials

Comments from Interviewees. In Fall 2006, telephone interviews were conducted among faculty around the country using *PET* materials in their courses. The purpose of the interviews was to learn about why the *PET* materials were chosen, how they were being used, strengths and limitations of the materials, students' responses to the curriculum, and suggestions for improvements. Of the 20 names for which contact information was provided by project staff, 16 individuals were interviewed. Below is a brief summary of comments.

- When participants were asked why they decided to use the *PET* materials, about half reported that they had been looking for a new program or were not satisfied with the program they were using. They found *PET* had characteristics they had been looking for, such as inquiry-based and hands-on learning, an emphasis on learning about learning, and a focus on conceptual learning.

- When asked about whether they had followed the *PET* cycles as they are specified in the program, three respondents stated they followed the program just as written, with no additions or deletions. Thirteen indicated they had primarily followed the cycles as provide; four of those supplemented the curriculum, five modified with some deletions, and three modified with both additions and deletions.

- When asked whether they had used the intended instructional strategies outlined in the curriculum, interviewees universally responded positively that they had used them.

- When asked if they had used the computer simulations, homework assignments, Elementary Students' Ideas (ESIs), or Scientist Ideas, all but one said they had. A few used some but not all of the ESIs.

- Interviewees were asked in what ways they used the computer-based faculty and student resource materials. All but one responded that they used the student resources, such as simulations, videos, and homework, as intended. All but two report using the faculty resources as well.

- The most frequently cited strengths of the *PET* program related to the pedagogy of the curriculum. Most of the interviewees commented on its constructivist, inquiry-based, hands-on approach that supports a sequencing of concepts, using the instructor as facilitator, and getting students thinking for themselves and working with other students.

- Asked about limitations, there were not consistently mentioned concerns. Most frequently noted limitation was the lack of mathematics, mentioned only by three interviewees.

- When asked about student response to the *PET* materials and methods, the interviewees overwhelmingly responded that student response was very positive. One said, *"The student course questionnaires that come back get the highest ranking on every dimension of the course."*

Evaluator Comments

These comments represent conclusions of the external evaluation team about the *PET* materials development and dissemination project. They are intended for use by the *PET* developers and other key stakeholders.

- In all college classes where *PET* materials were used, results of student content testing showed statistically significant positive changes from pre to post total scores. On individual items, the degree of change varied, but many scores for individual items increased 2 or more points from pre to post (out of 3-5 points). In only very few instances on particular test items in particular classes was there no statistically significant change from pre to post.

- The pre/post tests went beyond typical multiple choice formats. In addition to students being asked to select among a set of responses, they also had to provide a written justification for their response choice(s). This not only made the test more challenging, but provided a lot of insight about student thinking about the physical science concepts addressed in the test item.

- Pre/post test results for in-service teachers in summer workshops were consistent with results for students in undergraduate courses. For all total test scores and for almost every individual item score across workshop sites, there was a statistically significant positive difference from pre to post. Although workshop facilitators indicated it was challenging to cover all the *PET* topics in the 10-day summer workshops, this did not appear to seriously affect pre/post test score results.

- Test results were consistent in undergraduate classes of different sizes, different student demographics, different universities, different regions of the country, and different instructors facilitating the class. Positive changes in total pre- to post-test scores were statistically significant in all cases where *PET* materials were used.

- A quasi-experimental comparison group study (*PET*-based class compared with traditional lecture-based class covering the same material) at one university shows statistically significant differences in pre/post test results for both groups. However, pre to post gain scores (for the total test score) differed between students in the *PET*-based and traditional course, with students in the *PET*-based course making substantially greater gains. Although there was some variation for individual item scores, students in the *PET*-based course scored significantly higher on most of the individual items.

- As might be expected, pre/post test results are affected by whether the subject-matter of the test item was covered in the class/workshop. In classes where the instructor indicated that certain subjects were not seriously covered due to time constraints (in one instance, electricity; in another, light), scores on those items showed little or no change from pre to post.

- Analysis of the written explanations to questions in selected undergraduate classes showed a qualitative substantive improvement in the nature and accuracy of the responses. This would suggest that students had a better understanding of the concept addressed in the question (and could articulate it in writing) by the end of the class.

- Analysis of pre/post test scores based on the level of training received by an instructor indicated no statistically significant differences. There were statistically significant pre to post total score gains whether a class was taught by a *PET* developer, a collaborator (someone trained by *PET* developers and familiar with the earlier *Constructing Physics Understanding* materials), a field tester (those trained by the developers), or a colleague of a collaborator or field tester (who received some coaching from their colleague and used the on-line *PET* instructional support materials). Assuming that the instructor had adequate background in physics and/or physics education, the *PET* support materials (with availability of someone to provide one-on-one advice as needed) were helpful to non-trained instructors in effectively conducting *PET*-based courses. Interviews with the non-trained instructors indicated that help from their colleagues, careful review of the *PET* curriculum, and use of the web-based support materials helped them "get up to speed" on the curriculum.

- Although the sample was small, there was some evidence to suggest that when the instructor's beliefs about how physics should be taught to undergraduate students varied from the *PET* philosophy, student understanding as reflected in pre/post test results is less than in those classes where the instructor's beliefs were more consistent with *PET* and whose delivery of the program was more robust. The effects were also likely related to the fidelity of implementation of the *PET* curriculum.

- All field test faculty attempted to implement the *PET* materials as intended in order to get a more authentic and consistent "test" of the materials. Most were successful in maintaining fidelity of the intended curriculum, although a few found it necessary to make small modifications to the program because of course time constraints.

- Effective implementation of the *PET* curriculum requires instructors to serve as "facilitators," not "dispensers of information." Several field test faculty indicated this was sometimes challenging and frustrating because they had been accustomed to "giving answers." They also found this approach "takes more time to get through the material." However, most agreed that it was an effective way to improve teaching and learning. Most found students initially frustrated by this approach (having been accustomed to someone "just giving answers"), but as the term progressed, students appeared to become more comfortable with the instruction (some even indicated they needed to use this approach in their own future classrooms).

- Perhaps the most controversial and challenging component of the *PET* program for several field test faculty was the Elementary Students' Ideas (ESIs). Most field test faculty were accustomed to teaching physical science courses that included many pre-service elementary teachers (some taught courses designed just for this group). However, most courses focused only on the physical science content/ concepts. Sometimes more constructivist pedagogy was modeled by using it in the class, but specifically looking at how elementary students develop/convey physical science concepts had not been a part of their earlier repertoire. *PET* provided materials for them to address these issues. Many indicated frustration, at first, with the ESIs (as did many of their students), but as the materials were repeatedly used, faculty realized positive effects on their students. They also indicated they gained personal insights about student thinking because the elementary students were having the same "struggles" as their college students.

- In interviews with users of the final published *PET* materials, some indicated modifications of the *PET* program to better "fit" their course requirements—making additions, deletions, and adaptations of the *PET* materials. It is not unusual for instructors to modify commercial instructional materials to meet idiosyncrasies of their students and themselves. Effects on student learning of major modifications is unclear.

- The *PET* development team clearly had a well-framed vision for their final curriculum products. The "fine-grained" effort to pilot- and field-test the materials and make necessary modifications based on feedback resulted in innovative and high quality physics curriculum materials. The lead evaluator is an experienced science educator and has used a variety of instructional materials in courses and workshops. It is clear that the *PET* program is one of the most effective inquiry-based programs "I have seen anywhere." Evidence of impact from the evaluation of *PET* certainly confirms that.

Physics and Everyday Thinking (*PET*)

EVALUATION FINDINGS

Prepared by the External Evaluation Team
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EVALUATION FINDINGS: *Effects on College Students*

The primary target audience for *PET* is pre-service teacher undergraduate students. *PET* materials are designed as a curriculum and associated instructional and faculty support materials in a physics content course for prospective teachers. To determine the impact on student understanding of core *PET* concepts, pre/post content tests were administered in classrooms of the *PET* collaborators and field testers. The tests were administered in 45 different college courses between Fall 2003 and Spring 2005. The test was also administered in 5 summer in-service teacher workshops. Results are presented in a later section of this report.

- **Pre/Post Content Tests.** The tests served as one way to assess the effectiveness of the *PET* curriculum. University collaborators and field testers were asked to administer a physics test at the beginning and end of the courses in which they were using *PET* materials. The nature of the tests was consistent with the constructivist nature of the *PET* program—students had not only to choose a specific answer to the question, but also provide a rationale for their answer. A core purpose of the test was to assess student understanding (and ability to articulate that understanding) of the concepts depicted in the question, not just be able to “guess” from a set of prepared answers.

  The test items were created by the *PET* development team. Items were related to the specific “cycles” (topics) covered by the *PET* materials (described below). Each item was worth either three points or five points. Developers prepared a detailed scoring rubric for each item designed to assess the quality of written rationale. All scoring was done by one member of the external evaluation team.

  The original test included 5 items (for a total of 19 possible points). Subsequently, two items were added to better reflect the subject matter covered by the evolving *PET* curriculum (thus, the total possible points changed to 25). Below is a brief description of each of the items.

  Item #1: This item asks students to identify the forces involved when a soccer player kicks a ball straight up into the air and then catches it when it falls back down. Students are then asked to explain their answer. The highest possible score is 3.

Item #2: In this item students were asked to pick from a set of choices that best describes the motion of a puck being pushed by a hockey player with a "constant strength push." Students are asked to explain the reasoning behind their choice. The highest possible score is 3.

Item #3: For this item, students are told that a large block is on rollers so that it can move across a surface as if there is no friction affecting it. After it has started moving to the right, two men want it to continue in the same direction at a constant speed. Drawings of four possible situations are provided. Students are asked to indicate which situation would result in the block moving to the right at a constant speed after it has already started moving. They are also asked to explain their reasoning. The highest possible score is 3.

Item #4: Students are provided with a drawing of a young boy sitting on a bed looking at an apple. There is a lamp on his night table directly behind him, the only light source in the room. Students are told the ceiling and walls are painted a non-shiny white color. They are asked to draw on the illustration to show how the boy can see the apple, including arrows, and labeling what they draw. Then they are asked to explain how the boy is able to see the apple. The highest possible score is 5.

Item #5: Students were told about a boy with a wind-up car with a coiled spring inside. The boy holds the car on the floor, winds the spring, and then lets go of the car. The car speeds up quickly, then moves along at a nearly constant speed for a while, then slows down to a stop. Students are given four statements that could be made about what was happening to the car. Then the students are asked to identify the best statement to describe what was happening in terms of energy at four different points in the car's journey. For each they are asked to give their reasons for their choice. The highest possible score is 5.

Items #6: Students are shown an electrical circuit with a single battery connected to two identical light bulbs. Two characters, "Daryl" and "Luisa," offer their prediction about how the brightness of the two light bulbs would compare when the circuit is tested. Students were then asked whether they agreed with Daryl, Luisa, both of them, or neither of them. They were asked to explain their answer. The highest possible score is 3.

Item #7: Students are shown two different circuits with bulbs and batteries—one a single battery and bulb and the other with a battery and two bulbs on separate circuits. Daryl and Luisa predict how the brightness of a particular bulb in the first circuit will compare with the brightness of a bulb in the second circuit. Then students are asked whether they agree with Daryl, Luisa, both of them, or neither of them, and to explain their answer. The highest possible score is 3.

➢ **Test Sites and Procedures.** The pre/post content tests were administered by course instructors on the first day of class and just prior to the final course exam. Most courses were conducted over about a 15-week period. Pre- and post-tests contained the same items. Prior to the beginning of the course and near the end of the course, instructors received packets of materials from the evaluators, including the instructions for administering the tests, the actual test booklets, a student information survey (providing information about student status and background in science), and a self-addressed stamped envelope to return completed tests to the evaluation team. Instructors assigned code numbers to each student. The same code number was used on both pre- and post-tests so statistical analysis using matched pairs could be conducted.

The tests were administered in 45 different classes between Fall 2003 and Spring 2005. A total of 1119 students completed both pre- and post-tests. Students in one or more classes at the colleges or universities listed below (in alphabetical order) completed the tests. A detailed list of sites and schedule of administration of the test is found in the appendix.

- Ball State University (Indiana)
- Black Hills State University (South Dakota)

- Buffalo State University (New York)
- El Camino College (California)
- Furman University (North Carolina)
- Jamestown Community College (New York)
- Northwest Arkansas Community College (Arkansas)
- Purdue University (Indiana)
- San Diego State University (California)
- Southeastern Louisiana University (Louisiana)
- Tennessee Technological University (Tennessee)
- University of Arkansas (Arkansas)
- University of Idaho (Idaho)
- University of Michigan—Dearborn (Michigan)
- University of Minnesota (Minnesota)
- University of Nebraska (Nebraska)
- University of Wisconsin—Whitewater (Wisconsin)
- Western Washington University (Washington)

Twenty-five different instructors were involved in administering pre/post tests. These instructors were classified in five categories: 1) Original *PET* developers; 2) Collaborators trained in *PET* by developers (who had been very familiar with the earlier *Constructing Physics Understandings* materials); 3) Field testers trained in *PET* by developers (recruited from across the country with an interest in a constructivist approach to teaching/learning of physics); 4) Instructors who were colleagues of collaborators or field testers (and received some coaching from the trained collaborators or field testers, along with using the web-based professional development materials); and 5) No training or coaching on the use of the *PET* materials (a single instructor who was part of a comparison group study). All instructors had formal backgrounds in physics and/or physics education and had taught physics courses specifically for pre-service teachers or courses that included a large proportion of pre-service teachers (except two physics/physics education graduate students who had not previously taught such courses). College teaching experience varied from one year to several decades.

Three of the classes were lecture-based (with separate lab sessions); the rest were lab-based only. Number of students in lecture classes varied from 88 to 134; lab sessions varied from 8 to 34.

Student demographics varied from one institution to another, with eight classes having moderate (up to 25%) or high (more than 25%) minority student populations (primarily Hispanic or Arab American). Although most courses included a range of class levels, most were dominated by sophomores and juniors. Nearly all students had a least one (most had two or more) science classes in high school. Number of previous college-level science courses taken varied depending on the class level of the students, but most had taken at least one college science course prior to enrolling in the *PET*-based class. Nearly all the students enrolled in the classes were already or planned to be education majors.

- **Results from the Pre/Post Content Tests.** In order to determine the statistical significance of changes from pre- to post-test scores, a paired t-test was done on total scores. The charts below show results. For all sites, the change in scores from pre- to post-test was significant at alpha <= 0.01. This indicates that overall student responses to test items were significantly higher (based on the scoring rubric criteria) from pre- to post-tests. Detailed pre/post test reports for each class in which test data was gathered are available, including t-tests on individual items. A sample detailed report can be found in Appendix A of this report.

- **Fall 2003.** Tests were administered in 8 classes at 6 different sites. The chart below shows results of t-test analysis on total test scores.

Site	Number of Students	Pre-Test Mean	Post-Test Mean	Gain Score	Total Points Possible
A	7	4.4	13.1	8.7*	19
B	5	5.2	15.2	10.0*	19
C	28	4.9	12.7	7.8*	19
D	30	2.8	13.5	10.7*	19
E	77**	4.2	12.6	8.4*	19
F	20	3.5	12.6	9.1*	19

*Statistically significant change from pre- to post-test (alpha <= 0.01)
** Combines three classes at same site.

- **Winter/Spring 2004.** Tests were administered in 8 classes at 5 different sites. The chart below shows results of the t-test analysis on total test scores.

Site	Number of Students	Pre-Test Mean	Post-Test Mean	Gain Score	Total Points Possible
M	11	4.18	13.36	9.18*	19
C	28	3.71	10.93	7.22*	19
D	30	3.83	12.60	8.77*	19
D	26	3.38	9.58	6.20*	19
E	28	2.50	8.61	6.11*	19
E	24	2.63	8.88	6.25*	19
F	24	4.50	14.88	10.38*	19
F	11	6.27	14.73	8.46*	19

*Statistically significant change from pre- to post-test (alpha <= 0.01)

- **Fall 2004.** Tests were administered in 13 classes at 7 different sites. The chart below shows results of t-test analysis on total test scores.

Site	Number of Students	Pre-Test Mean	Post-Test Mean	Gain Score	Total Points Possible
G	11	10.27	16.27	6.00*	25
H	20	6.60	15.40	8.80*	25
H	15	5.73	14.80	9.07*	25
I	26	6.50	10.85	4.35*	25
J	97	6.39	10.91	4.52*	25
K	25	5.24	12.20	6.96*	25
K	20	6.20	11.90	5.70*	25
K	11	5.55	10.64	5.09*	25
E	23	5.00	10.91	5.91*	25
E	21	5.38	10.29	4.90*	25
E	29	4.72	14.24	9.52*	25
L	16	6.31	17.94	11.63*	25
L	13	4.92	16.62	11.69*	25

*Statistically significant change from pre- to post-test (alpha <= 0.01)

- **Winter/Spring 2005.** Tests were administered in 14 classes at 9 different sites. The chart below shows results of t-test analysis on total test scores.

Site	Number of Students	Pre-Test Mean	Post-Test Mean	Gain Score	Total Points Possible
N	12	4.92	13.08	8.17*	25
O	112	4.59	7.37	2.78*	25
O	16	6.44	13.12	6.69*	25
P	15	4.93	10.80	5.87*	25
Q	17	6.65	16.06	9.41*	25
G	23	5.74	16.65	10.91*	25
G	19	6.05	14.26	8.21*	25
G	21	7.71	18.29	10.57*	25
H	21	6.14	16.71	10.57*	25
H	15	7.80	16.87	9.07*	25
J	73	5.78	11.64	5.86*	25
L	20	4.65	13.35	8.70*	25
L	20	4.89	13.32	8.42*	25
R	8	7.30	11.20	3.80*	25

*Statistically significant change from pre- to post-test (alpha <= 0.01)

- **College Course Comparison Group Study.** A simple comparison study of pre/post test scores from a *PET*-based course and a traditional course was conducted in Winter/Spring 2005. Evaluators identified a university site with a *PET*-based physics course (conducted by an instructor trained in *PET*) and a regular physics course (not using *PET* materials but covering the same physics content and conducted by an experienced physics instructor who had not been trained in *PET*) being taught during the same semester. Both courses were available to undergraduate students, most of whom were enrolled in elementary pre-service education. The *PET* class was a lab-based course and the traditional class was a large lecture section. No special recruitment was done to encourage students to enroll in the *PET*-based course. Students self-selected for both courses and came from the same pool of students at the university.

  The seven-item *PET* test was administered to all students in both classes at the beginning of the semester in January and again at the end of the semester in April. These were the same tests administered in all the other *PET*-based classes described in this report. Administration, scoring, and analysis of results were the same for this comparison study as for the other *PET*-based classes. A summary of findings follows.

  A. Gain scores (Dependent variables are the item post-test score minus the item pre-test score for each student who completed both tests; the traditional and *PET*-based classes were compared using two-sample t-tests).

  - Gain scores differed between students in *PET*-based and traditional courses for total score and items 3 (large blocks on rollers) and 4 (light-apple/eye connection). Students in the *PET*-based class made substantially greater gains than students in the traditional course (average gain of 6.7 points for students in *PET*-based class and 2.8 points for students in traditional class).

B. Pre-tests (Two-sample t-tests on the pre-test scores, where the *PET*-based class is one sample and the traditional class is the second sample).

- When all data are used in the pre-test (including students who may have completed only one test), students in the *PET*-based class scored significantly higher on total score and on items 1 (soccer player), 5 (toy car), and 6 (single electrical circuit).

- The same conclusions are drawn when only paired data are used in the pre-test (including only those students who completed both tests). Students in the *PET*-based class scored significantly higher on total score and items 1, 3, and 6.

C. Post-tests (Two sample t-tests on the post-test scores, where students in the *PET*-based class comprise one sample and those in the lecture class the second sample).

- When all data are used in the post-test (including students who may have completed only one test), students in the *PET*-based class scored significantly higher on total score and items 1 and 5, as in the pre-test. In addition, students in the *PET*-based class scored higher for items 2 (hockey player), 3 (blocks on rollers), 4 (light-apple/eye connection), and 7 (parallel electrical circuits). No difference was found for item 6.

- When post-test scores are examined for paired data only (students completing both tests), students in the *PET*-based class performed better on the total score and items 1, 2, 3, 4, 5. No significant difference was found for items 6 and 7.

The data suggests that students in the *PET*-based class started out somewhat ahead of those in the traditional class and performed better than students in the traditional class on the post-test. The students in the *PET* class made significantly greater gains on the total score and for items 3 and 4. As noted above, students self-selected for both classes and came from the same student pool.

- **Analysis of Differences Based on Nature of Training in Use of *PET* Materials.** *PET* was not only a curriculum/instructional materials development project, but also involved development of professional development/training materials for college instructors intending to teach a *PET*-based physics course for pre-service teachers. Among the 45 classes in which the *PET* materials were field tested, the nature of training on the *PET* materials varied. Evaluators identified 5 levels of training for those who field-tested the *PET* materials in their classes (described in the earlier section, “Test Sites and Procedures”). The scores from pre/post tests were analyzed to determine if there were any statistically significant differences in results based on the nature of training received by instructors.

  It was determined that there was no statistically significant difference in pre/post test scores among the first four categories of training. Only the fifth level (no training or coaching on use of *PET* materials) was different than the others; the average score was lower than the others. (Readers should note that this is based only on one person in the level 5 category). However, these results suggest that if instructors have background in physics/physics education and use the on-line and other *PET* instructional and professional development support materials (and, perhaps, receive some coaching from someone trained in *PET*), they can successfully implement a *PET*-based course that results in significantly improved scores on pre/post student content tests.

- **Examples of Student Written Rationale for Answers on Selected Pre- and Post-Test Items.** All pre/post test items required students to provide a written rationale for their answers to the questions. Discussion in this report has focused primarily on an analysis of the actual test scores. However, the qualitative aspects of student responses to test items also provided insights into the effects of the *PET*-based courses on student thinking. Below are some representative samples of students' responses from pre- to post-tests when there was a substantial quantitative score change from pre to post (low score, such as 0, to a high score of 3).

SAMPLE RESPONSES—Item #1: This item asks students to identify the forces involved when a soccer player kicks a ball straight up into the air and then catches it when it falls back down. They are to choose all forces they think are present from this list: ***a.*** *A force of gravity pulling downward;* ***b.*** *A force from the kick pushing upward;* ***c.*** *A force of gravity pushing upward;* ***d.*** *A force pushing upward due to the motion of the ball;* ***e.*** *Some other force (you describe).* Students are then asked to explain their answer. The highest possible score is 3. To receive three points they must choose answer ***a*** with an explanation that gravity is always pulling downward.

Pre-Test Answer(s) Choice	Pre-Test Written Response	Post-Test Answer(s) Choice	Post-Test Written Response
a, b, c	The girl kicked the ball upward and therefore her force is making the ball travel up. But if it was not for the force of gravity pushing it back down the ball would continue to go up into the atmosphere. There can also be other forces affecting the ball, as well. The likely one could be wind also moving the ball.	a	The only force that is acting on the fall is the force of gravity because the ball has already been put into motion in the air and no longer has any contact with the soccer goalie.
a, b, d	Gravity pulls the ball or anything towards the ground. The impact of the kick upwards sends the ball up into the air despite gravity. The ball is moving in a circular motion, and with the kick, helps ball go upward.	a	Once the ball has left the foot it has no driving force on the ball. Therefore, the only force acting on it is the gravity pulling back down to earth. The ball will eventually change direction (downward) due to this force.
b, c, d	The foot is pushing the ball up. Gravity helps the ball up, but will also bring the ball down. The motion of the ball will decide which way the ball will go.	a	There is a gravitation pull from the earth acting on the soccer ball, pulling the ball downward.
b, d, e	The force of the kick is the main act which caused the ball to go in the air. Without the force from the kick there would be no ball in the air.	a	The force applied by the foot put the ball in motion and is acting on the ball as it goes upward. I think gravity is acting on the ball causing it to come back down.
a, b	The kick is what sets the ball in motion. Even though the ball is moving upward, the force of gravity is always present, keeping it from flying away by the force of the kick.	a	The only force that is on the ball at this moment is gravity. Although the ball is moving upward, gravity is pulling it back to earth. This results in a decrease in upward motion energy of the ball.
b, d	The force of the kick is continuing to push up on the ball until gravity forces it to come back down.	a	The only force acting on the ball is gravity.
a, b, d	Gravity is slowing the ball down. The kick makes the ball go up. The inertia is heading up.	a	Gravity is the only thing acting on the ball. Once the ball leaves the foot the foot is no longer acting on the ball.

SAMPLE RESPONSES—Item #2: In this item students are asked to pick from a set of choices that best describes the motion of a puck being pushed by a hockey player with a "constant strength push." Choices include: ***a.*** *The speed of the puck will continuously increase;* ***b.*** *The puck will move at a constant speed;* ***c.*** *The speed of the puck will continuously increase; or* ***d.*** *Something else—you describe it.* Students are then asked to explain the reasoning behind their choice. Highest possible score = 3. To receive 3 points they must choose ***c*** with an explanation stating that a constant force will result in a continuously increasing speed.

Pre-Test Answer(s) Choice	Pre-Test Written Response	Post-Test Answer(s) Choice	Post-Test Written Response
b	The constant strength push will maintain a constant speed, increasing or decreasing due to change in the hockey player's "g" speed.	c	We proved in class that a continuous force on an object in motion will continuously increase in speed.
b	If the stick is in constant motion then the puck would be also, because the puck is pushed by the constant force of the stick.	c	The speed of the puck will continue to increase because of the constant force that the hockey player is applying with the stick.
b	The constant strength push means that constant strength is being pushed on to the puck, causing the puck to maintain a constant speed.	c	With a constant strength push there is an unbalanced force acting on the puck which means an increase in motion of the puck.
b	The constant pressure will cause a constant speed.	c	When a constant strength is placed on any object it will increase. We learned about the same theory in class when using the fan carts—that when time and speed are constant the slope of the line will increase rapidly.
b, d	Until something or some kind of force stops it, it will continue—"once in motion, stays in motion." Does gravity play a role? My guess would be that eventually gravity would slow the puck down and in order to stay in motion another force or energy would need to play a role.	c	We learned that if an object experiences a constant push it will continually increase in speed. If friction does not play a role, it does so because the forces are unbalanced.
b	If constant force is applied to the puck without variation, the speed of the puck should remain the same. The ice is also smooth so friction won't slow it down.	c	As with the carts during our experiments, when there is no friction and a cart is pushed at constant speed, it would continually increase because no factors change its acceleration or direction to affect the speed, or constancy. The same holds true for a puck on ice.
b	I think that the speed at which the puck moves, which is pushed by the constant strength of the hockey stick, will stay consistent with the speed at which the hockey player is moving.	c	The speed will increase because there is no force working against the force of the stick. If it were to move at a constant rate then there would be equal forces acting on it in both directions.
b	If the hockey player is pushing the puck at a constant speed then the puck will move at a constant speed. The puck will only increase if there is another force involved.	c	The speed of the puck will continuously increase so the hockey player will have to catch up to the puck in order for him to push at a constant speed.

Item #2 continued . . .

b	The puck will remain constant if the force acting on it remains constant. Once the force changes—increases or decreases—the puck will react that way.	c	Due to our observations in class, if you continue to apply a constant strength push on an object, it will continuously increase in speed.

SAMPLE RESPONSES—Item #3: For this item, students are told that a large block is on rollers so that it can move across a surface as if there is no friction affecting it. After it has started moving to the right, two men want it to continue in the same direction at a constant speed. Drawings of four possible situations are provided with these labels ***a.*** *Pull to the right is stronger than pull to the left;* ***b.*** *No one pulls, either to the right or left;* ***c.*** *Pulls to the right and the left are of equal strength; and* ***d.*** *Only one person pulls to the right—no one pulls to the left.* Students are asked to indicate which situation(s) would result in the block moving to the right at a constant speed after it has already started moving. They are also asked to explain their reasoning. The highest possible score is 3. To receive 3 points, they must choose ***b* and *c*** and include a written explanation that both 'balanced forces' and 'no forces' acting on an object result in its speed remaining constant.

Pre-Test Answer(s) Choice	Pre-Test Written Response	Post-Test Answer(s) Choice	Post-Test Written Response
a, d	I think that situations a and d would result in the block moving to the right at a constant speed because, when the pull is kept constant, the block could continue to move when the initial push (energy) has dissipated.	b, c	Situation b and c would allow the block to move at a constant speed because the forces will be equal from both sides of the block.
a, d	a) It would move to the right at a constant speed because the pull to the right would overthrow the pull to the left because it is stronger. d) As long as the pull to the right remains constant, the speed also remains constant.	b, c	In order for an object to move at a constant speed the forces acting on it must be either balanced or non-existent.
a, d	a) Because the pull is longer to the right compared to the left, the box will begin moving right. With the lack of friction, it will continue right at a constant speed. d) Since only the right side is pulled, it will continue moving right and without friction, it will remain constant.	b, c	Because there is no friction present, the block will move at a constant speed until some other unbalanced force acts on it. Therefore, the two situations above will not affect the block's constant speed motion because the forces in these situations are balanced.
a, d	Because the pull is stronger to the right in these two situations.	b, c	b and c are correct because since there is no friction, the box will continue on at a constant speed and if forces are the same they equalize each other and the box will continue to move.
a, d	a and d are most likely to maintain a constant speed. The block will slow down and will need extra force. It will depend on what time the force is applied to maintain the speed.	b, c	If there really is no friction then both b and c will keep a constant speed, because there is no opposing forces only equal amounts of force in both directions will maintain a constant speed.
a, d	a) If both are pulling at a constant rate, but the right rate is a little stronger, constant speed. d) If only one person pulls to the right and they use a constant strength, the block will move at a steady speed.	b, c	To have constant speed you have to have the same amount of forces acting upon the block. Either two pushes and pulls of the same strength or no pushes or pulls at all. The net force needs to be zero.

EVALUATION FINDINGS: *College Courses/Faculty*

A key stakeholder and targeted audience for the *PET* materials are college faculty who teach physics content courses for prospective elementary teachers. Faculty was involved in various ways in this project, including the core management team that developed the materials and provided training to others on use of the *PET* curriculum. Collaborating faculty included people who had worked with management team members previously on other projects and were familiar with the basic approach to teaching and learning used in the *PET* program. Field test faculty included college/university physics/physical science teachers who were recruited from across the country. Over the course of the project, evaluators gathered quantitative and qualitative information from them about their insights and experiences with the *PET* materials.

- **Pilot-Test Collaborating Faculty Implement *PET* in Their Classrooms.** A draft of the CPU-*PET* curriculum for pilot testing was developed over the 2002-03 school year by the three curriculum developers. This material was assembled in notebook and electronic forms for presentation at a five-day workshop at San Diego State University (SDSU), June 23-27, 2003. The workshop had two major purposes: 1) to familiarize participants with the new *PET* curriculum and 2) pilot a workshop format (and associated content) for future use in the project.

  There were 16 participants in the workshop, including five collaborating faculty who were recruited to pilot test the *PET* curriculum in their home institutions during the 2003-04 school year (Black Hills State University, Buffalo State University, Furman University, University of Idaho, and Western Washington University), plus two of the project PIs (SDSU and Tennessee Tech). These individuals were familiar with the earlier CPU (Constructing Physics Understanding) materials that had been previously produced at SDSU. *PET* was based on this earlier work. Also included in the workshop were several faculty from SDSU who would be teaching sections of physics for elementary teachers using the CPU-*PET* curriculum, faculty from Tennessee Tech (TNTCH) who would be using the CPU-*PET* curriculum, and graduate students from SDSU and University of Colorado—Boulder (UCB) who would be using the curriculum.

  At the end of the five-day session, participants were asked to provide feedback about the workshop and materials for use by developers in revising the program for future use. The field testers (SDSU, TNTCH, and UCB faculty and graduate students) were asked to complete a 7-item questionnaire. The faculty collaborators participated in a 30-minute focus group-like discussion facilitated by the evaluator about the workshop and their future piloting efforts. The collaborating faculty also had an opportunity to provide feedback verbally in a debriefing session at the end of the workshop facilitated by one of the workshop participants. Below is a summary of the feedback.

  - **Part I: Written Feedback.** This section is a compilation of responses from field testers for each item on the questionnaire. Because some of this group did not attend all sessions of the workshop, they were asked to indicate the morning and afternoon sessions they attended. In compiling the information, responses have been coded based on the level of participation and the type of participant. Codes are shown in the box below.

Key to Codes:
FP = Faculty partial (only attended part of the workshop; all this group attended more than half the workshop)
FA = Faculty all (attended all of the workshop)
GA = Graduate student all (attended all of the workshop)

- **Item 1: Which activities, demonstrations, presentations, and/or materials were most useful in helping you understand how to implement CPU-*PET* curriculum? Why were they useful?**
  - FP 1- Video of college students utilizing the curriculum. The examples of the instructor interactions with the students provided an excellent model to use in implementing the curriculum.
  - FP 2- Hard to list them all. The combination of activities and discussion of the rationale for each activity was most useful. This really was critical for an understanding of the course goals.
  - FP 3- I found the videos from the *PET* courses especially helpful in understanding how the instructor ("learning facilitator") reacts to student "models" and explanations.
  - FP 4- I valued the set up as it was: Goals and intro first, methodically working through the curriculum in order. Inserts of videos and pedagogical issues. I liked the chance to ask questions at the start of each day. I liked how each activity began with an overview, then did the activity, then revisited. I had never done the fan cart activities. Doing was essential. Pace was just right. Having the activities and breaks allowed us to catch up or clarify ideas, for example on the activity where I got lost.
  - FA 1- No response provided.
  - FA 2- Going through the activities was important-I would eventually do it at some time-but it was a good experience to get through them with a group of new acquaintances, pretending to be students. The videos of real-life class periods was very enlightening.
  - FA 3- All the activities were useful. The workshop facilitators presented materials well and their explanation helped me to improve my knowledge about the CPU-*PET* curriculum.
  - FA 4- Magnetism--Cyde 3—figuring out the magnet model.
  - GA 1- The combination of activities (videos, activities, and discussion) worked well. They were useful because after we worked through what we thought students would think, we could "test" our predictions. Also the video of the facilitators teaching (in their classrooms) modeled what a class discussion might look like.
  - GA 2- I liked going through all of the activities. I liked the ESI videos being inserted in the appropriate places. However, I would have benefited more from the ESI "Goals Talk" on Tuesday and then examined each ESI activity where it was intended to be given to the students. Also the *PET* videos were useful.
  - GA 3- All activities, demos, presentations were useful, but connecting or using them with energy idea gave me a different perspective. Also watching college students as they are working on activities was the most helpful part.

- **Item 2: Which activities, demonstrations, presentations, and/or materials need revisions to make them more useful to you in implementing the CPU-*PET* curriculum? What are your ideas for improving them?**
  - FP 1- A demonstration of time management issues and group management strategies-e.g. how to keep student discussions brief but informative, how to respond to students who "got it" who are frustrated with waiting for others to catch up. This was covered by the conference leaders. I would have appreciated additional input from participants.
  - FP 2- The last cycle on energy is simulator-heavy. I don't see how to do this with simple equipment. This way of teaching is so different from normal; I haven't had time to think about changes.
  - FP 3- I could better comment on this question <u>after using</u> the *PET* curriculum for a semester.
  - FP 4- On first day, I would like to have had knowledge that there would be web site support. a) Especially equipment lists and sources (ex. Mylar), b) Types of exams. OK to play with the site at later time. I wish there were two predication icons: 1) prediction which was an expected observation and 2) a different icon for tentative explanation (hypothesis).
  - FA 1- No response provided.
  - FA 2- No response provided.
  - FA 3- None
  - FA 4- I think the material is very good. However, I am sure issues will come up depending on the students. Then the instructor can make changes accordingly.

  - GA 1-Overall scheme of timing for cycle activities, homework and ESI for a sample one-semester or 1 quarter course. Provide suggestions about which pieces may be omitted or glossed over if there is a lack of time.
  - GA 2- However, there were too many of these *PET* videos on Wednesday and the latter of this day's videos was too long. So on Wednesday, too many videos and too long.
  - GA 3-At the last cycle there are too many topics/things squeezed in. Maybe, putting them in different cycle such as electricity and heat and energy would be a good idea.

- **Item 3. Please comment on the content, handouts/support materials, organization/format, time frame, facilitation, or other elements of the workshop. What were the strengths? What were the weaknesses? Be specific.**

  - FP 1- I think that some of the concepts/activities could have been addressed in a shorter period of time (i.e. seemed to be some "dead" time). Otherwise, all other elements were excellent, no need to change.
  - FP 2- Strengths: Volume and specificity of materials. The clear relationship between intent and implementations. Weakness: Limited topics are covered over an extended time frame. Students are not acquiring facts at a high rate.
  - FP 3- Time frame. I would have to look on the website to further investigate the recommended allotted time for each discovery activity, discussion, and conflict/idea resolution session.
  - FP 4- I like the order in the notebook. Keeping types of items separate is essential. (I have tried sequential with types mixed together. It doesn't work.) If they used a Post-It note on the activity, homework, and ESI and move it forward, they can quickly go from section to section. I liked switching groups. I got to know 2 sets of people and got interesting feedback from both.
  - FA 1- No comment provided.
  - FA 2- I thought the schedule, length of time spent on sessions were fine. On-campus accommodations would have helped a little for me, maybe not for others.
  - FA 3- Organization and format of the workshop were the strength, and support materials. No weaknesses noticed.
  - FA 4- Strength: Organization facilitates concept understanding. Weaknesses: The length of time, I guess depends on institution but also can be modified by instructor.
  - GA 1- Strengths-Actual participation in activities. Videos of students participating in same *PET* activities in facilitator's classes, interaction with other participants. Weaknesses: Cycle 6-long and covers many topics. Could be broken into 2 cycles.
  - GA 2- All of these elements were good.
  - GA 3- One weakness, maybe not weakness but question, is it possible to balance force motion and electricity part, in terms of time and focus. Or make curriculum spread over two semesters and apply the same things for electricity. I enjoyed seeing all theoretical things I've learned in application such as starting with students' ideas and using and building curriculum around it.

- **Item 4. Was the workshop adequate to prepare you to organize and begin implementing a class using CPU-*PET* curriculum and web-based material?**

  - FP 1- Yes, I felt the preparation was more than adequate.
  - FP 2- Yes. I would not been able to understand how to conduct this kind of course without this workshop. A very different philosophy.
  - FP 3- Yes. I could not imagine teaching/facilitating a class next semester without attending this workshop. In addition, I felt that the facilitator's in-class videos helped me understand the structure of the CPU-*PET* curriculum.
  - FP 4- YES and to guide my faculty who are not here (I hope. Depends on their willingness.) However, I am glad we can use the CPU-*PET* materials. I am delighted that I only need computers for access to the web. No loading software or regular printing. I fought for two days to get the other classroom set up the old way so that we could use PA 119.
  - FA 1- No comment provided.
  - FA 2- I feel that I could go out and do a *PET* course on my own. The videos and detailed coverage of the cycles were very helpful.

  - FA 3- The workshop was more than adequate. I really learned and gained a great deal of information and I am ready to implement it in my class.
  - FA 4- Yes. Now I have an idea of how the whole curriculum might work. Also the input from experienced faculty helps. They suggest issues or problem to watch for.
  - GA 1- Yes
  - GA 2- Yes. I feel confident I could implement *PET*.
  - GA 3- I hope so, but because I'm not implementing it immediately, I've tried to focus on other things such as sequence of activities rather than applying them.

- **Item 5. What else would you like to say about CPU-*PET* curriculum/web-based materials or the workshop?**

  - FP 1- I think the CPU-*PET* framework can serve as an excellent model for other science content courses for elementary teachers.
  - FP 2- I'm impressed with the coherence of the idea and its implementation. To emphasize understanding and how ideas are developed is a different approach from the more typical emphasis on maximum coverage of material. The curriculum shows the care that went into making all parts support course goals.
  - FP 3- It is obviously a well planned, well thought out physics/learning curriculum. I am delighted that the computer activities/simulations will be available for student use outside of the classroom via the web. This provides a great learning tool students can use (over and over) at their pace.
  - FP 4- 1) I like that the students will have written materials of their own rather than materials where the group worked on the computer and later printed. That gave me, as a participant, a chance to make personal notes, create a list of energy terms, not the sequence of pedagogy, etc. 2) I very much like how the light activities have been changed to focus on seeing first. I like the way we did the non-shiny reflection activity. Cycle 5. 3) Having people who have had some or a lot of experience with one or more parts of the course/activities makes the experience richer, 4) Got lost on last videos (light)—perhaps shorter segments?
  - FA 1- It would have been useful to explain what school of thought/theme this group was promoting vs. other efforts in progress. Being quite ignorant of education (me), what alternative approaches are "out there." Can this program be extended (or another course) to provide a set of experiments (possible examples on DVD) that a grade school teacher can then use in the classroom?
  - FA 2- Now it's difficult to comment on an approach so different from the physics teaching I've done for the past 14 years. I was pleased at the low level of Educationese in the discussions.
  - FA 3- Great workshop, web-based materials, and CPU-*PET* curriculum.
  - FA 4- I think having this workshop for actual teachers will help them to visualize the entire curriculum. Show teachers possible flaws in software, training for use of software also.
  - GA 1- The *PET* curriculum may be useful to more than elementary school teachers.
  - GA 2- No comment provided.
  - GA 3- No comment provided.

- **PART II: Group comments from field test group (facilitated by member of the group).** The following summarizes comments provided by one or more persons in the field test group during the debriefing session at the end of the workshop.

- Some were concerned about "invented words." Others said this was not a problem, because students "wouldn't remember them anyway."
- Some concerned about letting students go without drawing real conclusions on some things (especially the current electricity issues raised during the workshop). There was a general concern that somehow students should come to a conclusion about the topics.
- Some thought the ESI video materials might be inappropriate because the topics covered are not grade-level appropriate, while others thought this was not a problem—the purpose of the ESI videos was to help understand elementary student thinking about the topics.

- Because of state-mandated tests, should "you teach ideas or facts." This was a concern because of the heavy emphasis on ideas/concepts in the CPU-*PET* curriculum.
- Nearly everyone was "If not overwhelmed, at least well-whelmed." They all said they couldn't teach the CPU-*PET* curriculum without the workshop.

- **PART III: Comments from collaborators during end-of-session focus group discussion.** Below is a summary of comments provided by one or more persons in the collaborating faculty group during the debriefing at the end of the workshop.

  - **Strengths and weaknesses of the workshop:**

    - Doing the activities and then talking about each activity very important. Focusing not just on one kind of activity, but spending time on all types of activities important. Then making connections between the activities very important.
    - Watching the pre-service teacher videos very useful and important part of the workshop.
    - Going through the specific activities of the CPU-*PET* curriculum to see how different some are from the original CPU materials. Because of the different backgrounds about CPU, not as necessary to successfully learning how to use the *PET* curriculum. The workshop provided the tools to teach the CPU-*PET* program and to teach it in a new way.
    - If you think you are going to have problems back at your home institution about this curriculum or approach to teaching/learning, address the issue head on. It would be useful to have a bibliography or other "foundational" literature/articles regarding constructivist teaching/learning, especially targeted at physicists.
    - The exercises in the program were explicit to the nature of the teaching.
    - A good overview/guide to the curriculum/content would be useful, showing connections/sequence of learning.
    - Plant "ringers" or "seeds" among workshop participants to raise issues.
    - Focus on the coherence of the materials during the workshop. It is more obvious at the end of the workshop, but would be useful to help people understand it as the workshop unfolds.
    - Have someone from SDSU faculty come to next year's workshop to speak about their experiences in implementing the CPU-*PET* curriculum. Fred may try to meet periodically with SDSU faculty using *PET* to get feedback about their experience with it.
    - Is this a good course for anybody—not just teachers, but other students with non-science majors. This program models "how to think about thinking." Isn't this just as important for non-teachers?
    - Need to spend more time with the college student (and ESI students) for those not familiar with CPU (the "uninitiated')

  - **Preparation for teaching the CPU-*PET* curriculum back at home institution:**

    - Produce sample syllabus
    - Develop specific objectives for each activity, "Students will . . ." This would be useful when implementing the curriculum.
    - Make explicit the purpose, role of particular activities in the curriculum as they are being done.
    - Explicitly relate the "Pedagogy Guided by Principles of Learning" as the activities are conducted during the workshop.
    - Provide pre-program materials for workshop participants to "prime the pump," such as evidence for the value and effectiveness of the CPU-*PET* approach to teaching/learning and challenges in implementing the program.

  - **Other Discussion:**

    - Can you let pedagogical issues emerge from an immersion with the content of the program?
    - When are people ready to appreciate the deeper issues of pedagogy/learning and how do we prepare them for this?

- **Field Test Faculty Implement *PET* Curriculum in Their Classrooms.** Faculty who teach physics/physical science courses for prospective elementary teachers were recruited from across the country to serve as field testers for the revised *PET* curriculum. Fifteen individuals participated in a one-week *PET* Workshop in Summer 2004. These faculty (and, in some cases, colleagues back at their home institutions) used *PET* materials to teach their regular or newly created courses for pre-service elementary teachers. These faculty members were asked to respond to a set of interview questions about their use of *PET* materials in their courses during the 2004-05 school year; some interviews were conducted in December 2004, others in Spring 2005. Fifteen interviews were conducted with instructors from 12 academic sites, including 8 universities and 4 community colleges. A summary of their responses are shown below.

  - **Creating courses or adapting *PET* to current courses.** At all sites, courses were developed or modified to use the *PET* materials. At one site, a course was offered, but was not held because of low enrollment. In most cases, the materials were used in lab-based classes, although they were adapted to a large lecture class at one site.

  - **How Closely *PET* Curriculum was Followed.** At 8 out of 12 schools the *PET* course followed the curriculum just as it was designed or with relatively minor modifications. At 5 of these sites all cycles were completed. One instructor commented that it was “easy to teach,” it “went just as they said it would in San Diego.” At a sixth site the complete program was planned but due to lack of enrollment the course was not held. At 2 sites, a university and a community college, the intention was to complete the full *PET* program, but time ran out before Cycle 7 was completed.

    At 3 sites the curriculum was significantly modified due to time constraints. In each of these cases Cycles 1-4 and parts of 5, 6, and 7 were covered, as recommended by Fred Goldberg. At one site the *PET* course was offered in a very abbreviated form due to the college’s slow and sporadic acquisition of equipment and materials. The instructor improvised the curriculum according to the materials that were available, covering Cycles 1-3. The full curriculum is planned for next year.

  - **Changes Made to the Curriculum.** Instructors at 4 of the sites added content and/or assignments to the curriculum. At 2 of the sites where the program was completed in full, instructors added materials for the second semester the course was taught. One instructor added materials on Electricity and Magnetism to Cycle 5 and a unit on Light and Color after Cycle 6. In addition, this instructor assigned a paper carried over from a previous physics education course. The instructor reports no problem fitting these things into the timeframe. At the other site, CPU materials on Static Electricity were added between Cycle 3 and Cycle 4, some parts of *PET* Jr. were brought in at the end of the semester, and a “learning commentary” assignment was added to meet university writing requirements. This added 2-3 days.

    Additional materials or requirements were also added at 2 of the sites where the program was modified to cut out parts of cycles due to time constraints. At one, the students were required to do class presentations on *PET* Jr. activities, as well as to put together portfolios, which are required by the university and were developed from *PET* homework. At the other, additional content, especially “social physics” topics such as global climate change, and some *PET* Jr. materials were covered in a lecture that is part of the course, while the *PET* curriculum was followed in the lab that accompanies the lecture.

At the site that was severely restricted due to lack of equipment, the full program is planned for next year with an additional service learning assignment, where students will use *PET* Jr. materials in local schools and write an essay on the experience.

- **Comments and Suggestions about the Curriculum.** Respondents universally agreed that the *PET* curriculum is outstanding: “I really like the curriculum, and my colleagues do too.” “Very well structured,” “very integrated,” “cohesive,” “well designed,” “excellent the way it builds on previous material,” “runs very smoothly,” “really takes students through the process,” “finely crafted.” One instructor noted that multi-modal instruction and especially kinesthetic learning is well suited to the students. Several instructors commented on how informed and well thought out the program was: “They deliver—they’ve gotten out the bugs.” “It’s clear they have worked with enough students that they know what they’re likely to be thinking and what experiments are needed to dissuade them of misconceptions.” “I would like to give all of you guys a medal for coming up with *PET*.”

  Overall, respondents indicated satisfaction with the physics content covered in *PET*. They were pleased that it addresses the nature of science and reasoning based on evidence. One stated that it meets university goals of addressing critical thinking and communication. Another noted that in a previous course they had tried to cover too much content, and students did not do well. With *PET*, students were learning what was covered and ending up with a more positive attitude, as measured by course evaluations.

  There were also suggestions for improvement. Several individuals were concerned that the program is weak in specific areas. Individuals suggested adding materials on the following: static electricity, electrostatics, electric charges and magnetism, parallel and series circuits (preferably to be covered before magnetism), light and color, astronomy (north, south, etc.), and shadow (time of day, etc.). One instructor wanted more on “how could you convert from this form of energy to this form to this form?”—suggesting adding homework specifically for Cycle 5, Activity 2. Another would like “a wrapper that wraps a unit on static electricity and Cycle 4 together so that they compare and contrast the models they’ve developed for static electricity and for magnets.” One instructor whose previous course focused on modern and social physics commented that it would be good to be able to cover some social physics content, in which students are usually quite interested, such as global climate change and ozone depletion.

  There was also a concern mentioned by a few respondents that there seems to be a trend toward requiring a chemistry-physics combination course.

  Several of the instructors noted the students became frustrated with the amount of repetition they encounter in the curriculum. Most of the instructors indicated that they understood the function of the repetition, though they also saw that it could be tedious. One instructor was concerned that the material may be too easy for the population who take the class. On the other hand, a few stated that there is too much material to cover in the time available. Indeed, as noted above, six of the sites were unable to complete all seven cycles. Among those sites, however, one has a 14-week semester and 2 have lecture/lab courses with somewhat reduced lab time for the *PET* curriculum.

  One respondent misses the depth achieved with the CPU program. But others indicated that the breadth/depth balance in the *PET* program, especially compared with CPU, is appropriate for the philosophy of the course and more useful for the needs of the population, and students “really learn” what they cover.

- **Equipment and Materials.** All sites but one had or were able to build or obtain the equipment and materials needed for the course, though in a few cases at the last minute, and in one or two cases they had to adjust slightly for older models of equipment or software. Two respondents mentioned difficulties finding horseshoes. All had computers available in the lab, some laptops which had to be set up each time, but most permanent computer stations. All but one site reported the technology went very smoothly. At the site with difficulties the problem was in the local computers. At one site a lab technician set up all equipment for each lab, allowing the instructor to focus on the class.

  All respondents reported the students used the simulators as suggested in class. Some instructors, especially those who had previously experienced technical difficulties with CPU, had downloaded the software onto classroom computers to reduce the likelihood of "crashes," but they had very few technical problems and most ended up accessing them on the website anyway. The instructors were enthusiastic about the simulations and reported students liked them, appreciating the opportunity to see clean data. There was some concern, however, that students do not understand that simulations are not "real experiments."

- **Homework.** All respondents reported they assigned the homework as suggested in the *PET* program, or very close to it. Several commented that the problem with the homework is that it tends to be "wordy," creating time-consuming work for the instructor. One solution was to have students bring homework to class and go over it there. One instructor with a 3-hour lab found that students had "extra" time in the middle of the lab period, and since the homework assignments would often naturally fall at about that point in the schedule, students were allowed to use that time to do homework in class.

- **Elementary Students' Ideas.** All instructors reported they used the Elementary Students' Ideas (ESIs) as suggested, or very close to it, both in class and as homework. Almost all had computer projectors for the in-class ESIs (one is still waiting for delivery). Some students were able to access them on home computers, and some had to plan ahead to do ESI homework on school computers, depending on hardware and software compatibility.

  The response to the ESIs was mixed. Instructors on the whole reported that they thought the ESIs were valuable, and several identified them as a strong point of the program, noting that they allow the students to see elementary children grappling with the same questions and making the same predictions that they themselves have just made on their experiments. "They resonated with that."

  However, several instructors commented that many of their students did not seem to understand why the ESIs were relevant to them as future teachers. One suggested that pre-service teachers may just not be equipped to use the ESIs because they lack experience in the classroom. "They were unable to make the leap from 'I am learning' to 'I am evaluating someone else's learning.'" She suggested the ESIs might be better used in methods classes. Several instructors noted that they had students who did not seem to pay careful attention to the videos, but there were other students who found them helpful, even exciting, and did get the connection between their own learning process and the process of the elementary students. In addition, one instructor commented that the ESIs might help "weed out" students who do not really want to be teachers before they are too advanced in their academic careers.

  The primary problem with the ESIs was in implementation. Several instructors commented on problems with the quality of the videos, the difficulty being able to hear and clearly understand what was going on, due to actual noise and “data noise.” Even with transcripts, some students had difficulty sorting out what they were looking for. One respondent suggested replacing the ESIs with videos presenting the same scenarios, but scripted and performed by actors, with controls for audio clarity. The other problems mentioned were that the ESI homework tended to be tedious and time consuming for the instructors, and students tended not to give it as much attention as desired until the instructor made the expectations clear.

- **Scientist’s Ideas.** All respondents reported they used the Scientist’s Ideas (SI) as suggested, or close to it. Several commented on how much the students appreciated them. One instructor noted students will ask for the SI if they miss that day in class. Another stated, “They look forward to the Scientist’s Ideas. They are so used to having the facts given to them… Here they are discovering things on their own, but they understand that eventually they will be given sort of the bible… They are really looking forward to seeing how that compares to what they developed in their class.”

  A few instructors noted the value of Scientist’s Ideas for giving students awareness of how scientists talk about these concepts. “They like knowing that this is the language people use and this is how they think about it.” However, the concern was raised by one instructor that the students have spent time developing their own concept of the meaning of words they have been using, “and now all of a sudden we throw these other words at them.” One instructor found the students were not reading the SI carefully and were ending up with misconceptions, so she began asking them to underline certain sentences and review those. Another pointed out that the SI are presented in a very neutral manner, and while that may be intentional, this instructor believes it is important to give the more important concepts more emphasis, which he does during a short lecture. Yet another raised the concern that some students seemed to be “looking ahead” to the SI to get the correct ideas before following through on the lesson.

- **Groups.** All of the respondents had their students work in groups. Responses to using groups were overwhelmingly favorable, although some cautionary comments were made. The primary concern was that groups can have “bad chemistry” and become dysfunctional, causing students frustration. Most instructors commented that they changed the groups two or more times during the course of the semester, which helped. One instructor assigned groups originally according to confidence level (as determined by a survey conducted at the start of class), then, after some grades had come in, according to ability, with students of “high,” “medium,” and “low” ability in each group. This seemed to work out well.

  The other concern about groups was the management of students’ different paces, both within groups and from group to group. Some students are inclined to race ahead, in some cases by skipping the “harder questions.” Others need plenty of time to work through the concepts. Whole groups can end up waiting for other groups to get to the point of sharing data. Students can become frustrated either by having to wait or by feeling rushed.

- **Tests.** Most of the instructors reported they had used the *PET* tests as provided. Those who taught the class a second semester were confronted with the problem that those tests were now “out there” and so developed new versions of the tests to use. At one site the *PET* tests were used for review and the instructor developed quizzes that “look fairly different.” He reported the students handled the quizzes successfully. One instructor notes the students found the *PET* tests to be “very challenging.” On the whole, however, the instructors did not indicate anything extreme in the grades students were achieving in the *PET* courses.

- **Website.** All of the instructors reported they personally used the *PET* website, most stating they used it "all of the time" and commenting that it was very helpful, especially for planning, pacing, anticipating what the students will be thinking, and guiding instruction. Several commented on being frustrated that the website was not complete. They stated they kept hoping it would "catch up" as they worked their way through the cycles. One thought the timing information on the website was more accurate for earlier cycles than for later cycles.

- **Identified Strengths.** The instructors were asked to identify strengths of the *PET* course. Below is a summary of aspects respondents consider to be strengths, grouped by major category.
  - ***Curriculum***
    - Curriculum covers nature of science and reasoning based on evidence, addresses critical thinking and communication
    - Content much better than CPU; good breadth (more useful than depth for this population), the connections in *PET* are better than in CPU; *PET* is more coherent than CPU
    - Curriculum is finely crafted, well put together, leads students through things, very tight coherence, straightforward, straightforward to students, too
    - Well integrated, excellent the way the course builds on previous material; leads them through very carefully
    - They have done the research for what students think and can get them to face those issues; "it's clear they've worked with enough students that they know what they're likely to be thinking and what experiments are needed to dissuade them of misconceptions"
    - The students struggle through the concepts, then they figure it out; the curriculum really takes them through that process
    - A lot of repetition, which is good for some students, though the repetition is a strength and a weakness—a strength pedagogically, but tedious
    - Carries a theme all the way through (energy transference); "by the end they were drawing energy diagrams that were really, really good"
    - Students learn much better and a have more positive attitude than with CPU
    - Scientist's Ideas wrap up and allow the validating students are seeking
    - Able to cover a lot because this program removes the distraction of worrying about formulas and math and students could just concentrate on what was happening
    - "I have taught for many years, and used conceptual books—I love those books—but the truth is, at the end of the course my students have not learned that much. I am hoping there is going to be a greater percentage of people with a better understanding of science"
    - "Got done and said, 'yes, we'll definitely do that again,' which is different from what we've said about everything we've tried in the past"
  - ***Website***
    - Website support for instructors is very useful for planning, pacing, anticipating what the students will be thinking, guiding instruction, "I use it all the time," "I haunt the website"
    - Technically runs very smoothly
    - Website solutions guides very helpful "because not everything on there is extremely intuitive"
    - Website support good up to the point where it is incomplete
  - ***ESIs***
    - ESI is a major strong point; the same thing happens among the students as among the kids on ESIs—same questions, same information, same frustrations
    - Students see the kids experiencing what they themselves experienced; it "shakes up their thinking," they get excited, some of them see the implications for their own future teaching
    - ESIs were a good idea, but a weakness in implementation because it was hard to hear and understand well enough to make the connections and students were frustrated
    - ESIs allow students to see what working with kids is really like, can help weed out students who really don't want to be elementary teachers
  - ***Instructional Strategies***
    - Use of hands-on, interactive teaching, modeling of methodology, allowing construction of own models, use of real-time graphing, white boards, discussion among students

    - Use of simulations a major strong point; no computer or simulation problems
    - Good way to teach, students are interested, some are adopting the philosophy, pleased at how well they've advanced
    - Modeling pedagogy; helps them to recognize how students frame things
    - Students see how scientists frame things, gain appreciation of how science functions as a whole
    - Saw changes in understanding and perception; saw students "cross some kind of boundary" from wanting to be shown to going ahead and doing it themselves
    - Students involved in their own learning, active all the time, discussing ideas; the process of reflection on what you've done is critical
    - Students really advanced over the semester, had to give up what they thought they knew—very impressive
    - On the first day all the students but one responded to a survey by saying they were not interested in science. By the end, most seemed to have changed their attitude; they were pretty excited, learned all it took was paying attention, thinking about what they were doing
    - Students started coming into the lab whenever it was free, wanting to work there
    - "This lighted a new passion in me"
    - Good discussion in class; *PET* students scored higher than non-*PET* students on survey question: "I learn physics better when I discuss it with other people"
    - Structure keeps "hangers on" from relying too heavily on group members

- **Limitations and Suggestions.** Respondents were asked to identify limitations of the program. Below is a summary of limitations, grouped by major category. In some cases respondents provided suggestions. These are included at the end of each category.
  - ***ESIs***
    - ESIs are a good idea but quality is problematic, it can be hard for students to hear what is going on and sort out what they need to observe from the video due to noise (audio and data noise)
    - Students lack enough classroom experience to use ESIs fully, some students don't respond to ESIs or don't always read them carefully
    - Suggestion: create ESIs performed by actors with sound control for clarity
    - Suggestion: use both ESIs and *PET* Jr. in a methods course
  - ***Homework***
    - The documents required for this program are very wordy, assignments have a lot of writing, can be difficult for some students (ESL students or students weak in reading/writing)
    - Homework creates a lot of grading, especially the ESI papers
    - Simulators and ESIs require certain hardware and software—students were not happy at first about having to come to school for those parts of the homework when they could not access them on home computers
    - Need to focus more on getting students to cite evidence
    - Suggestion: put idea journal back in (as in CPU) so students really recognize what is observation, inference, good evidence
  - ***Curriculum***
    - Weak in static electricity, electrostatics, electric charges and magnetism, parallel and series circuits (preferably to be covered before magnetism), and light and color
    - Educational community requirements are evolving toward chemistry/physics combination course, which could make it hard to convince people that this class is acceptable/transferable
    - Does not cover "social physics" content, such as global climate change and ozone depletion
    - Students complain curriculum is very repetitive; they are being asked the same thing three and four times; they see this as tedious, a waste of their time; one instructor thinks for the audience the material is too easy
    - There is only one version of the tests; used first semester and now have to generate new versions because the first test is "out there"
    - Don't get the depth you get in CPU
    - Would be nice to be able to tie in more directly with what is being taught in local schools
    - Suggestion: add materials to address these areas, add homework for C5A2
    - Suggestion: incorporate a benchmark at the end of the class to convince people they really learned

- ***Instructional Strategies***
    - Students want validation, they are not as comfortable with this methodology as they are with lecture, they are resistant and frustrated at first with not getting answers, though most come to accept it and some value this strategy
    - It is hard for instructors to avoid validating, requires training and support
    - Website needs to be completed to support instructors through later cycles
    - It can be hard to get students going in discussion, especially the full class
    - Students can be frustrated by their groups, can have groups with bad "chemistry" or dysfunctional groups
    - Pacing issues: fine line between giving them enough time to figure it out and wasting time. Some students "freaked out" when they were hurried, others rushed through and were bored, some raced through, skipping the harder questions; problem with different paces of different groups; students having to wait 10 minutes for another group to be ready to go on
    - Takes a lot of faculty and TAs for the size of the class
    - Instructor can be spread thin going from group to group to encourage discussion, help with observations
    - Instructors wanted to go to a conference but could not find other instructors willing/able to teach the course while *PET* staff were gone; another noted "backsliding" of students while he was gone and a substitute covered.
    - Limited by lab space; can't run as many students through the class as needed
    - Limited by availability of the equipment
    - Putting this into place was a lot of work at first ("but worth it")
    - Suggestion: change group makeup regularly
    - Suggestion: make tutorial videos with Fred Goldberg demonstrating teaching techniques available through website

- **Mini-Case Studies: *PET* Implementation in Action.** As part of the evaluation of *PET*, two field test sites were selected to conduct brief case studies about the implementation of *PET*. Both were selected on the basis of their proximity to the evaluation team headquarters (within easy driving distance) to facilitate site visits and reduce costs. One served primarily small town and rural students; the other urban and suburban students. Data was gathered through site visits, observation of classroom activities, interviews with field test faculty, review of pre/post course test data, and review of various documents and course materials. Data was collected in Spring 2005 during the *PET* field test phase. What follows are summary descriptions of the implementation of *PET* at these two sites.

CASE 1: MAJOR COURSE REVIEW

About the Field Test Faculty Member. The instructor holds master's and doctoral degrees in physics. He taught one year elsewhere before taking this position. The position appealed to him because it emphasizes physics education, which is a research interest of his. He states physics "wasn't always easy for him, so he understands about the challenges of learning it." He was also attracted to this university because of its focus on disability programs. In addition to physics education courses, he teaches a "physics of music" course, which is taken primarily by music and speech pathology students.

About the University. This midsized state university is located in a small rural Midwestern town, population about 14,000. It is a 45 minute drive from two major cities. The community is predominantly Caucasian with little ethnic diversity.

There are about 10,500 students at the university, about 90% of whom are undergraduates. The university draws mostly from a 100 mile radius, with many commuters. Fewer than 10% of the students are from out of state. A high percentage is the first in their families to attend college. It is common for students to complete their first two years at a community college, then transfer to this university. The top students in the region tend to go to a larger nearby state university.

A specialty of this university is that it provides high quality services and programs for people who have disabilities. Another unique feature is that students do not purchase their texts. All texts are "rented" through student fees. However, for the *PET* class, students must purchase the manual and accompanying CD.

About the Physics Department. The Department of Physics is located in the College of Letters and Sciences. There are about 40 students majoring in physics and about 500 students enrolled in physics classes during any one semester. All are undergraduates, most taking courses either in astronomy or physics education. There are currently about 240 students majoring in elementary level education programs.

There are five faculty members in the Department. Four positions have been lost over the last few years, although they are slated to gain a position in the near future. There is one tenured position (the Chair), 2 untenured faculty on tenure tracks (the *PET* instructor is one), and 2 academic staff. With 3 years in the department, the *PET* instructor is the third most senior faculty member. Because of the small size of the department, he serves on numerous committees and maintains a large class load.

Classroom Setting. The science building is undergoing construction for remodeling and enlargement. During construction, the *PET* courses are taught in a large basement lab room with rows of tables in the center and six 4-person work stations, each equipped with a desktop Apple Power Mac G3 computer, around 2 sides of the room.

The instructor has an adjoining lab/office equipped with computers, counters, storage cabinets, and sink. A cheerful sign: "Has gravity got you down...?" hangs on the outside of the classroom door announcing help available from the Society of Physics Students. In one corner of the hallway upstairs there is a full-sized 3D mirror with a sign stating: "So you can see yourself as others see you … Provided by your user-friendly Physics Department."

About the Class Using the *PET* Curriculum. The *PET* format is used in a course called Physics for Elementary Teachers. This 4-credit class meets twice a week for 2 hours and 20 minutes, and is listed as a general education, lab-based class. Students in education are required to take a lab-based physical science class and they prefer a 4-credit class to best fit their overall requirements. Enrollment is not restricted to education students, "but that is who takes it." It is capped at 24 students per section due to the number of computer stations. Two sections are offered per semester.

The instructor observes better attendance in this class than in his non-*PET* classes (one student was overheard by the evaluator commenting to a peer, "This is the only class I haven't skipped"). When students miss a class they are able to turn in homework and come in during office hours to use the *PET* simulators, so they can make up all but the group interaction and discussion. The groups are assigned and changed twice during the semester.

Observing Classes: *PET* in Action. The university has a 15 week semester. The site visits were conducted shortly after spring break, when the class was beginning to “wind down.” The instructor notes he “front-loads” the course schedule to allow for any delays during the semester, so the pace is slower near the end. He plans a 15 minute break during class, but sometimes discussion prevents a break or students choose to keep going and leave early. Two sections of the class were observed over two class days. The students in both classes appear to be predominantly white females. There were a small minority of males, individuals who appear to be of Asian or Latin ethnicity, and individuals who appear to be non-traditional in age.

On the first day of observation, students were to take the Cycle 5 exam so they sat at the center tables. Class opened with announcements, return of homework, and opportunity to ask final questions before the test. Several students asked questions, to which the instructor replied with prompts about their observations. He engaged in discussion but did not give direct “answers.” He provided all the time the students needed for questions. Students were then given the test and invited to take a break when finished. When they returned, they sat at pre-assigned workstations around the room in groups of up to 4 for the C6A2 activity portion of class.

During the remainder of the class, the students worked in their groups. They looked through their materials, there was a small amount of talk comparing ideas, and one student in each group wrote the group consensus on the white board. When talk wound down, the instructor invited each group to report their ideas to the class. The groups generally agreed in their reported ideas. The instructor clarified what each group was reporting and pointed out similarities but made no evaluative or explanatory comments.

Next, the whole class watched an ESI video clip. The groups then discussed what they watched, having been asked to think about certain statements made in the video as well as “what preconceptions do the children have?”

After watching a second video clip, students were asked to compare what the elementary students thought with what they themselves had thought. They searched through transcripts, jotted notes, and the conversation increased within the groups as they began writing on the white boards. Once again they shared what they found, with one person speaking for each group and the instructor reflecting their responses. There was no discussion at first, but some open-ended questions from the instructor elicited a little more discussion in the class as a whole.

On the second observed class day students went directly to the workstations for Cycle 6 Activity 3 and 4. After announcements they began looking through their materials and consulting with one another about what they were doing. The routine of writing on the white boards and sharing ideas with the whole class was repeated.

Each group then collected equipment and conducted the investigation. There was some discussion within groups, asking each other about how they were supposed to set it up and what they were seeing. There was some off-topic talk, but most students appeared to be engaged in doing the activity. The routines of sharing results were repeated. Where there were differences among groups there was more questioning by the instructor, getting the class to think about other cases or other ways to see what they had found, until differences seemed to be explained away.

The instructor was watching, cruising around the room, occasionally checking in to see how a group was doing. His attitude was friendly and nonjudgmental, but focused and intent. The students responded to him with respect but obviously felt comfortable talking with him. When they asked questions he posed questions back, suggested other conditions to try, or provided other examples: “What if you held it like this?” More than once he stated, “When in doubt, experiment!”

Creating a New Course. This instructor has studied modes of learning extensively and states that “to improve physics learning you need hands-on, group interaction, and instant graphing.” When he arrived at this university the first thing he did was to get white boards to use in the classes he was to teach. There were two general physics courses. One of them was a Descriptive Physics course for education students that was 3 credits, lecture-based, and used a textbook heavily. He developed his own curriculum for teaching that class, breaking up the class lectures as much as possible with demonstrations, small experiments, and discussion using the white boards. Naturally he was drawn to the *PET* format when he came across it two years later. While he previously had used many activities with students similar to these, the *PET* program “is far more sophisticated, better thought-out, appears to have better and more in-depth analysis of phenomena, and has better documentation on how the course relates to many of the required ‘standards’ than anything I could hope to create.”

After two years on the job, he received a call from an academic advisor in the Curriculum Department who has a special interest in the physics education course. The advisor is a former elementary and high school science teacher and currently advises elementary education students and teaches their required methods course. A long-time advocate of active learning theory, her methods course is constructivist in nature. She states that physics and biology are the “two bases for everything in science” and ought to be the two science courses all elementary education students take. She was calling to suggest that he change his course by adding a credit and making it lab-based. Changes in university requirements were coming which would influence students to select 4-credit, lab-based science courses preferentially, and she was concerned they would not take the physics course if it did not meet these criteria.

The instructor states his reaction to the idea of changing the course was, “You’ve got to be kidding—I’ve just got my notes all fixed.” Subsequently, he attended the AAPT meeting where he saw the presentation on *PET*. *PET* involved kinesthetic learning, white boards, real-time graphing. The course was lab-based and 4 credits. It was just what was being requested of him, and it was already put together. He was particularly attracted to the ESI video clips in which his students would be able to see children learning physics in the context of their own learning experience. He also saw that it could help with his own research in physics learning.

For his department to change the physics education course it offered at the time to the *PET* course would require a curriculum change, and “wisdom is that new faculty should not get involved in curriculum change.” But he broke the golden rule because of the warning about upcoming changes in student requirements as well as the potential opportunity to do more research. “I’ll let you know in 4 years whether it was worth it.”

The Department and its Chair at the time were supportive. He quickly received their approval for the revision, but the request was refused at the college level because the changes were too substantial to qualify as revision. He had to make this a new course. Finally, everything came together just in time to offer the first two *PET* sections in Fall 2004, including the required equipment.

The instructor reports that in those first classes the students were very aware of the change in class style. He uses the *PET* curriculum just as it is published, with very little exception. He adds a paper assignment for which students take a physics quiz at the beginning of the term, select three items they answered incorrectly, and write a paper exploring their thinking on those items, and he adds experiments for Electricity and Magnetism and Light and Color. On the first day students are told that this class is different: the instructor is a facilitator, not a validator. There have been mostly positive comments from the students, most indicating they enjoyed it, they thought it a worthwhile change, and they liked that at the end they have a ready-made packet to use with kids in the future.

Program Strengths and Limitations. The instructor notes that about 50% of the students in the *PET* courses are getting an A. This bothers him, but he has found that student misunderstandings usually come out earlier in the semester in this class than in others. Poor students do well if they come to class regularly, it gives the good students a chance to help others, and average students are kept more actively engaged than in the previous lecture-based course. The instructor believes part of the reason *PET* is successful is because the class is self-selective. "These students are going to be teachers, so when they are working in groups, they want to help each other learn."

The department chair indicates that students taking the course are responding to it in "a more positive manner" than the previous course. "We will never go back to more conventional instruction for pre-service elementary teachers . . . We as a department hope the program is adopted nationwide!" The curriculum advisor who supported the program all along agrees. She says that students she advises to take the class come back to her with positive comments. She sees the ESI component as one of the greatest strengths, "That's one of the ways I persuade students that this class is for them." She also believes the instructor is important to the success of the class—"He's a very good 'idea shepherd.' He has a good center on what is the concept he wants students to get, but they have to get it, he's not going to give it to them." She states that the program is based on the idea that the students' ideas matter and their capacity to have ideas matters.

The *PET* course is now formally approved in the curriculum at this university. The one concern the instructor has is that because of the university's unusual book rental policy, if anyone starts charging too much for the lab manual or charging extra for on-line access to the *PET* website, that could create problems with offering this class in the future.

Student Views of the *PET* Courses. Seven students volunteered to talk with the observer confidentially about the *PET* course. All were education majors or minors, and while this class is not required, it satisfies a requirement for each of them. All reported they are comfortable with the grades they are getting in this class. All reported that on the whole they thought it was a good class: "You really learn it." One nontraditional student said she had not valued labs before, but "I now know what I didn't know. I may take the lab courses in the other sciences. I had no idea what I had not learned before."

The students all commented on appreciating the hands-on, lab-based nature of the course. They noted different aspects they found helpful, including the simulator, the ESIs, and the lab manual with the structure laid out so that "you know what you'll be doing." One student commented that even the homework was meaningful. They noted that the instructor is easy to talk to and approachable, and they appreciated his giving them all the time they need so that they never felt overwhelmed.

On the other hand, several of the students noted that the slow pace and repetitive nature of the work were often tedious or boring. "In experiments and homework you are asked the same question repeatedly sometimes. Didn't we just answer that a few steps ago?" Several commented that they'd noticed class members becoming impatient. "At the end of the first day I was furious. I thought, 'we're going to be teaching third graders, we're not the third graders.' But I have had a total conversion. Now I really believe in the way it's taught; now I really understand. It's my favorite class now. I'd love to incorporate this exact thing into a classroom with kids. It can be hard, though, because the tiny little bit of new information each time can be tedious. I've noticed two of my group members get really frustrated."

All of the students commented on the fact that the instructor does not give definitive answers. "I really like the way the instructor stimulates our thinking by asking questions, doesn't answer, or answers with questions. You learn more if you have to work for it, you own it." But again, while several students expressed appreciation for the value of this approach, all of them noted that it can be frustrating and confusing. One said, "I like it just fine. It makes you think outside the box. But I know people who don't like it that it's driven by the individual, then the group, and only last by the instructor." One noted that it was a drawback not to hear more from the instructor. "We don't get much of his talent or knowledge. He's reduced to a facilitator." Another stated, "There are so many ideas among the students, you become confused, not sure what is right and what is wrong. There's a certain point the teacher needs to step in and tell us what we're supposed to have learned…Being confused you're not learning anything." One student said, "Sometimes the discussion doesn't come to a consensus of what's 'right,' and I leave class wondering which it is…I go and look it up, but I'm also afraid it will get stuck in my head wrong and I don't realize it." Another said, "Sometimes I come into class and feel stupider when I leave." There was concern that without definitive answers, "if your opinion was wrong you get it wrong on the test."

The students also commented on advantages and drawbacks to working in groups. In general they reported they enjoyed the groups, as long as the groups were working together well and did not include people who were frequently absent or "whipping ahead." "You need to attend to how the groups are doing, whether there's a big disparity in the pace among group members." "The groups are critical. If they are not working well together it's very frustrating." There was appreciation for the instructor's having changed the groups twice, so that they got to know other students' thinking and a bad group experience did not last the whole semester.

CASE 2: INTEGRATING *PET*

About the Field Test Faculty Member. This long-time physics instructor and science educator has taught physics in a regional university and served as chair of the physics department in the College of Education. He has been active in various state and national physics education projects, including Operation Physics and Constructing Physics Understanding. He is one of two faculty members who teach physical science content courses for pre-service elementary teachers. This faculty member had been using many components of the earlier PIPS physics program. Following his training at San Diego State University, he replaced his curriculum with the *PET* curriculum. In addition, he trained his colleague on the *PET* program (who did not attend the *PET* training). Also a long-time physics instructor, this second faculty member also implemented *PET* in his lab sections. Subsequently, both have modified *PET* to incorporate favored components from other programs, keeping the core concepts and approaches from *PET*.

About the University and Physics Department. This comprehensive higher education institution is located in a large urban area and serves students from the region, including African American and other minority populations. Approximately 8,600 students are enrolled. There is a cooperative arrangement between the College of Education and College of Arts, Sciences, and Letters (CASL) in which CASL faculty teach science courses, including physical science, to prospective elementary and secondary teachers. Two to four sections of physical science for elementary teachers are offered each term. There are currently two faculty members from the physics department who teach these courses.

Classroom Setting and Course. *PET* courses are taught in two-hour sessions twice a week in a science laboratory setting (in short summer session, two 3-hour sessions and one 2-hour session). There are 24 students in each section. Most students are juniors or seniors. Labs were fully equipped so students had supplies and equipment to work in pairs or groups of four. Each team had use of a laptop computer with access to the *PET* simulations and other on-line materials through a course webpage. Teams are re-constituted three times during the term to “mix up” students so they can work with different people over the course of the term.

During the field testing of *PET*, both instructors were attentive to implementing the curriculum as intended by the developers as much as possible. In the 14-week session, they were unable to fully complete all cycles, deleting one and leaving out portions of two other cycles. They also had to maintain some college-wide requirements—three portfolios, one on personal growth, one on technology, and the third on state curriculum standards. These portfolios are added to a web-based personal portfolio as they complete their various courses. In the case of this class, some of the *PET* homework assignments were modified to fit the portfolio system.

Observing Classes: *PET* in Action. Evaluators observed two lab sessions in each of the two faculty members’ classes during a winter-spring semester. Additionally, one session was observed during a summer term. In all cases, instructors were closely following the *PET* curriculum, incorporating the hands-on investigations, ESI activities, and other lesson components. Observations were conducted about 2/3 of the way into the semester, so students were also accustomed to working together in small groups and conversing about their investigations.

Both instructors were using appropriate questioning strategies to engage students in whole group and small group conversations. One seems to be more effective than the other in getting students to discuss ideas in the whole group. He says, “I always ask students to provide evidence for their ideas or their claims.”

The other has tried to enhance small group conversation. He says, “It is hard to get students going in a discussion. Sometimes they have an answer and everybody else nods their heads—‘Yes, that is what I would have said’—it seems to bomb with the whole group. So I go around to each table and have a discussion there. It means me having to do it five times, but I think it is working when I see more participation.”

These classes have large proportions of non-traditional students which changes the dynamics of the class. These students are more attentive and more demanding of the instructors. One says, many are “mature women going back to school. And sometimes they are very, very alive and ‘with it,’ wonderful students, and other times they can be incredibly difficult to get them to think in more complex ways. They are highly motivated, but they have been out of school for a long time.”

Program Strengths and Limitations. An important organizing framework for *PET*, according to the lead faculty member, is “‘interactions’ as a unifying theme . . . it is better than energy because I think energy is too abstract. And I think you need the interactions or forces in order to do energy well, and without that, energy just becomes too abstract to use.”

Another strength is the instructional approach of *PET*. The constructivist approach used in *PET* “recognizes that students learn best if you get them engaged in what they’re about to learn . . . that you have them explore their ideas and at the end of that you explain what’s going on . . . students have to make sense of what they’ve learned.”

Both instructors made use of the “Scientist Ideas” component of *PET*. “We don’t hand those out until we are about to finish a cycle and then that becomes the final discussion on the topic. We pass them out, they read them, and then we talk about them—‘What’s the evidence for each of these ideas?’ That works fairly well.” Students “don’t come in with a lot of understanding of science. They have the usual misconceptions. They don’t have a lot of science background. Some of them had some physics in high school, but that is rare. So you have to deal with the usual Aristotelian mind-set and yank them out of the past. A lot of the *PET* activities are very good in helping them do that. It is interesting to see them watch ESI movies and see the elementary students having the same misconceptions as they do."

Instructors have tried to implement the ESI materials both in class and as homework assignments. They both believe these are very useful activities, although they take a lot of time. Some students respond favorably to them; others in a negative way. However, according to one instructor, "They recognize that this is what they're going to have to do in the future and they get practice for it.

EVALUATION FINDINGS: *In-Service Elementary Teachers*

Five of the Pilot-Test Collaborators (instructors who received *PET* training from developers and were already familiar with the *Constructing Physics Understanding* materials) conducted summer workshops for in-service teachers in Summer 2004. Sites included Black Hills State University (South Dakota), Buffalo State University (New York), Furman University (North Carolina), University of Idaho (Idaho), and Western Washington University (Washington). At Western Washington there were two groups (one that completed all seven *PET* cycles and one that completed only the first three cycles). Collaborators recruited in-service elementary teachers to participate in a 10-day summer workshop. Participants received a stipend and access to science equipment for use in their classes during the school year. They were expected to fully participate in the *PET* external evaluation (pre/post surveys, pre/post workshop content test, and follow-up interviews) and to field test at least one *PET* Jr. unit during the 04-05 school year and provide feedback to developers about strengths and limitations of the unit. What follows is a summary of findings from the pre/post workshop tests, pre/post surveys, and follow-up interviews.

A total of 131 teachers participated in the five complete workshops (an additional 81 participated in the Western Washington short-version workshop).

- Grade levels represented in the five full workshops were as follows: K-2nd = 16.8%; 3rd-5th = 43.5%; 6th-8th = 18.3%; 9th-12th = 5.3%; Special Education = 3.0%; Not identified = 12.9%.
- Teaching experience was as follows: 1-3 yrs = 19.8%; 4-6 yrs = 18.3%; 7-10 yrs = 16.7%; 11-15 yrs = 13.7%; 16-20 yrs = 8.3%; >20 yrs = 12.9%; Not identified = 9.9%.
- Formal science background included: Science major = 9.1%; Science minor = 11.4%.

- **Pre/Post Content Tests.** At the beginning and end of each workshop, participants were asked to complete the *PET* content test (described in an earlier section of this report, "Effects on College Students, Pre/Post Content Tests"). A total of 116 teachers in the four full-version workshops took both the pre- and post-tests; 81 took pre- and post-tests in the short-version workshop. Analysis of test results is shown below.

  - **Paired t-tests.** As with pre/post test scores from college classes, the statistical significance of changes from pre- to post-test scores were determined for test results in the in-service teacher workshops. A paired t-test was done on total scores and individual item scores. The chart below shows results of t-tests on total scores. For all workshops, the change in scores from pre- to post-test was significant at alpha = <= 0.01. This indicates that overall participant responses to test items were significantly higher (based on the scoring rubric criteria) from pre- to post-tests. Detailed pre/post test reports for each workshop are available, including t-tests on individual items.

Workshop Site	Number of Participants	Pre-Test Mean	Post-Test Mean	Gain Score	Total Points Possible
AA	21	5.14	16.24	11.10*	25
BB	18	6.22	17.56	11.33*	25
CC	32	6.41	15.88	9.47*	25
DD	10	3.50	14.00	10.50*	25
EE1	81	2.68	7.70	5.02*	9**
EE2	35	8.03	17.60	9.57*	25

*Statistically significant change from pre- to post-tests (alpha <= 0.01)

** This group completed only the first three test items related to first three *PET* cycles.

- **Pre- and End-of-Program Survey of *PET* Jr. Field Test Teachers.** *Physics for Elementary Teachers* (*PET*) is a National Science Foundation-funded project to develop instructional materials and associated professional development materials to improve college-level physics education. The instructional materials have been designed for use in college-level physical science courses for prospective (pre-service) elementary teachers and workshops for practicing (inservice) elementary teachers. In Summer 2004, elementary in-service teachers participated in 10-day workshops at five locations across the United States, facilitated by *PET* Faculty Collaborators who had been trained in the use of the *PET* materials. These sessions served as field test sites of the *PET* curriculum in a teacher workshop setting. In addition to using the core *PET* curriculum as the basis for the workshop, teachers also learned about and received a set of *PET* Jr. materials, physical science units for elementary students that corresponded to the core *PET* curriculum. Workshop participants were expected to field test one or more of the *PET* Jr. materials in their classrooms during the 2004-05 school year. In addition, it was assumed they would use content and instructional strategies they had learned in the workshop in the regular science curriculum.

  At the beginning of the workshop and again in Spring 2005, participants were asked to complete a survey designed to gather information about their perceptions of their preparedness to teach particular science topics, preparedness to facilitate particular activities during their science lessons, use of particular instructional strategies, and frequency of student participation in particular activities during science lessons.

  What follows is an analysis of responses to the two surveys, showing how teachers' perceptions have changed from pre-program to end-of-school-year. One hundred twenty-three completed the pre-program survey and 61 completed the end-of-school-year survey (about 50% of the pre-program respondents). This report is based on data from the 61 teachers who completed both surveys. A comparison of results of the pre- and end-of-program survey data was done using paired t-tests to test the null hypotheses that ratings did not differ between the pre-program and end-of-program survey. Two-sided alternative hypotheses were used at a 0.05 significance level for each test. The tables below show the changes in mean scores that occurred pre to post, highlighting those that represented a statistically significant change.

  - **Profile of Teacher Participants.** Based on a series of survey questions about themselves, the following describes the 61 teachers that are the focus of this report:
    - Grades taught by respondents: K-2=11; 3-5=28; 6-8=11; 9-12=7; K-5=3; Substitute teacher=1
    - How often they teach science: 1-2 times/week=5; 2-3 times/week=8; 4 times/week=8; 5 times/week=24; Varies=12; No response=4
    - Length of a typical science lesson: 15-30 min=4; 31-45 min=24; 46-60 min=21; 61-90 min=3; Over 90 min=3; Varies=2; No response=4

- Number of years teaching experience: 1-3 yrs=13; 4-6 yrs=9; 7-10 yrs=12; 11-15 yrs=8; 16-20 yrs=8; >20 yrs=10; No response=1
- Science major in college: Yes=13; No=46; No response=2
- Science minor in college: Yes=9; No=48; No response=4

- **Familiarity with State and National Standards.** Teachers were asked to rate their familiarity with state and national curriculum standards on a 4-point scale, with 1 = low familiarity and 4 = high familiarity. At the end of the program teachers felt somewhat more familiar with state and national standards than they did at the start of the program. See Table A below.

Table A

						Overall Mean		
Pre-program (04) vs. Follow-up (05)		1	2	3	4	2004	2005	Change
a. Familiarity with science standards and benchmarks of teacher's state	2004	10%	29%	36%	25%	2.75	3.18	0.4*
	2005	2%	15%	47%	36%			
b. Familiarity with national science standards	2004	25%	44%	21%	10%	2.16	2.48	0.3*
	2005	15%	33%	38%	13%			

*Statistically significant change from pre to post (alpha <= 0.05)

- **Level of Preparedness to Teach Science Topics.** Teachers were asked to rate their preparedness to teach various physical science topics related to *PET* on a four-point scale, with 1 = not adequately prepared to 4 = very well prepared. The results are presented below in the next seven tables (Table B1 to Table B7). The first table shows average ratings and percentages in the pre-program and follow-up surveys. The six that follow provide more detail on how the teachers' ratings changed between pre-program and follow-up

Table B1

						Overall Mean		
Pre-program (04) vs. Follow-up (05)		1	2	3	4	2004	2005	Change
a. Motion of objects	2004	25%	44%	23%	8%	2.15	3.18	1.0*
	2005	2%	18%	41%	39%			
b. Forces	2004	28%	44%	18%	10%	2.10	3.10	1.0*
	2005	0%	22%	46%	32%			
c. Magnetic interactions	2004	31%	33%	31%	5%	2.08	3.10	1.0*
	2005	0%	12%	47%	41%			
d. Light	2004	33%	36%	20%	11%	2.07	2.88	0.8*
	2005	9%	27%	32%	32%			
e. Electric circuit	2004	39%	28%	26%	7%	2.00	3.00	1.0*
	2005	7%	19%	42%	32%			
f. Energy	2004	36%	38%	20%	6%	1.97	2.90	0.9*
	2005	2%	32%	41%	25%			

*Statistically significant change from pre to post (alpha <= 0.05)

Tables B2 to B7 allow the reader to track the specific changes from pre- to post-surveys for each of the science topics. For example, in Table B2, preparation to teach motion of objects, 15 of the participants rated their level of preparation at 1 (not adequately prepared) in the pre-program survey. In the follow-up survey, none of the 15 rated themselves at level 1; instead they were spread 5, 5, and 5 across levels 2, 3, and 4 (the highest level). The shaded diagonal cells count the participants whose rating did not change from pre to post. In the cells to the left of the diagonal, the rating fell from pre-program to follow-up, and in the cells to the right of the diagonal the rating increased. A review of these six tables shows that the participants' beliefs about preparedness increased in each topic.

Table B2

a. Preparation to teach Motion of Objects

Pre-program Survey Rating		Follow-up Survey Rating				
		1	2	3	4	Total
1	Count	0	5	5	5	15
	Percent	0%	33%	33%	33%	100%
2	Count	1	4	13	9	27
	Percent	4%	15%	48%	33%	100%
3	Count		2	6	6	14
	Percent		14%	43%	43%	100%
4	Count			1	4	5
	Percent			20%	80%	100%
Total	Count	1	11	25	24	61
	Percent	2%	18%	41%	39%	100%

Table B3

b. Preparation to teach Forces

Pre-program Survey Rating		Follow-up Survey Rating				
		1	2	3	4	Total
1	Count	0	6	7	4	17
	Percent	0%	35%	41%	24%	100%
2	Count		6	14	5	25
	Percent		24%	56%	20%	100%
3	Count		1	4	6	11
	Percent		9%	36%	55%	100%
4	Count			2	4	6
	Percent			33%	67%	100%
Total	Count	0	13	27	19	59
	Percent	0%	22%	46%	32%	100%

Table B4

c. Preparation to teach Magnetic Interactions

Pre-program Survey Rating		Follow-up Survey Rating				
		1	2	3	4	Total
1	Count	0	6	9	4	19
	Percent	0%	32%	47%	21%	100%
2	Count		1	11	8	20
	Percent		5%	55%	40%	100%
3	Count			7	11	18
	Percent			39%	61%	100%
4	Count			1	2	3
	Percent			33%	67%	100%
Total	Count	0	7	28	25	60
	Percent	0%	11%	47%	42%	100%

Table B5

d. Preparation to teach Light

Pre-program Survey Rating		Follow-up Survey Rating 1	2	3	4	Total
1	Count	5	5	8	2	20
	Percent	25%	25%	40%	10%	100%
2	Count		9	5	8	22
	Percent		41%	23%	36%	100%
3	Count		1	4	5	10
	Percent		10%	40%	50%	100%
4	Count		1	2	4	7
	Percent		14%	29%	57%	100%
Total	Count	5	16	19	19	59
	Percent	9%	27%	32%	32%	100%

Table B6

e. Preparation to teach Electric Circuits

Pre-program Survey Rating		Follow-up Survey Rating 1	2	3	4	Total
1	Count	3	7	10	3	23
	Percent	13%	30%	44%	13%	100%
2	Count	1	4	6	6	17
	Percent	6%	24%	35%	35%	100%
3	Count			7	8	15
	Percent			47%	53%	100%
4	Count			2	2	4
	Percent			50%	50%	100%
Total	Count	4	11	25	19	59
	Percent	7%	19%	42%	32%	100%

Table B7

f. Preparation to teach Energy

Pre-program Rating		Follow-up Survey Rating 1	2	3	4	Total
1	Count	0	9	9	4	22
	Percent	0%	41%	41%	18%	100%
2	Count	1	10	8	2	21
	Percent	5%	48%	38%	9%	100%
3	Count			7	5	12
	Percent			58%	42%	100%
4	Count				4	4
	Percent				100%	100%
Total	Count	1	19	24	15	59
	Percent	2%	32%	41%	25%	100%

- **Class Activities.** Teachers were asked to rate how well prepared they were to facilitate various science class activities on a 4-point scale, with 1 = not adequately prepared and 4 = very well prepared. Results are shown in Table B8. The subsequent tables (B8-B14) provide more detail on how the teachers' ratings changed between pre-program and follow-up.

Table B8

						Overall Mean		
Pre-program (04) vs. Follow-up (05)		1	2	3	4	2004	2005	Change
a. Leading a class using investigative strategies	2004	2%	16^	57&	25%	3.05	3.43	0.4*
	2005	2%	2%	49%	47%			
b. Managing a class engaged in hands-on/project-based work	2004	0%	12%	49%	39%	3.28	3.70	0.4*
	2005	0%	0%	30%	70%			
c. Making connections within and between science subjects	2004	3%	38%	36%	23%	2.79	3.30	0.5*
	2005	0%	12%	47%	41%			
d. Making connections to real-world situations	2004	2%	30%	46%	22%	2.88	3.47	0.6*
	2005	0%	7%	40%	53%			
e. Helping students take responsibility for their own learning	2004	2%	15%	47%	36%	3.18	3.52	0.3*
	2005	0%	7%	34%	59%			
f. Recognizing and responding to diverse students needs	2004	2%	21%	46%	31%	3.07	3.46	0.4*
	2005	0%	5%	44%	51%			

*Statistically significant change from pre to post (alpha <= 0.05)

Tables B9 to B14 allow the reader to track the specific changes from pre- to post-surveys for each of the class activities. For example, in Table B9, preparation to facilitate leading a class using investigative strategies, only one participant rated his/her level of preparation as 1 (not adequately prepared) in the pre-program survey. In the follow-up survey that person rated him/herself at level 3. The shaded diagonal cells count the participants whose rating did not change from pre to post. In the cells to the left of the diagonal, the rating fell from pre-program to follow-up, and in the cells to the right of the diagonal the rating increased. A review of these six tables shows that the participants' beliefs about preparedness increased in each topic.

Table B9

a. Preparation to facilitate leading a class using investigative strategies						
		Follow-up Survey Rating				
Pre-program Survey Rating		1	2	3	4	Total
1	Count	0		1		1
	Percent	0%		100%		100%
2	Count	1	0	7	2	10
	Percent	10%	0%	70%	20%	100%
3	Count		1	20	14	35
	Percent		3%	57%	40%	100%
4	Count			2	13	15
	Percent			13%	87%	100%
Total	Count	1	1	30	29	61
	Percent	2%	2%	49%	47%	100%

Table B10

b. Preparation to facilitate managing a class engaged in hands-on/project-based work

		Follow-up Survey Rating				
Pre-program Survey Rating		1	2	3	4	Total
1	Count	0				0
	Percent	0%				--
2	Count		0	4	3	7
	Percent		0%	57%	43%	100%
3	Count			12	18	30
	Percent			40%	60%	100%
4	Count			2	22	24
	Percent			8%	9%	100%
Total	Count	0	0	18	43	61
	Percent	0%	0%	30%	70%	100.0%

Table B11

c. Preparation to facilitate making connections within and between science topics

		Follow-up Survey Rating				
Pre-program Survey Rating		1	2	3	4	Total
1	Count	0	1		1	2
	Percent	0%	50.0%		50.0%	100%
2	Count		6	15	2	23
	Percent		26%	65%	9%	100%
3	Count			13	9	22
	Percent			59%	41%	100%
4	Count			1	13	14
	Percent			7%	93%	100%
Total	Count	0	7	29	25	61
	Percent	0%	11%	48%	41%	100%

Table B12

d. Preparation to facilitate making connections to real-world situations

		Follow-up Survey Rating				
Pre-program Survey Rating		1	2	3	4	Total
1	Count	0		1		1
	Percent	0%		100%		100%
2	Count		3	7	8	18
	Percent		17%	39%	44%	100%
3	Count		1	14	12	27
	Percent		4%	52%	44%	100%
4	Count			1	12	13
	Percent			8%	92%	100%
Total	Count	0	4	23	32	59
	Percent	0%	7%	39%	54%	100%

Table B13

e. Preparation to facilitate helping students take responsibility for their own learning

		Follow-up Survey Rating				
Pre-program Survey Rating		1	2	3	4	Total
1	Count	0		1		1
	Percent	0%		100%		100%
2	Count		2	4	3	9
	Percent		22%	45%	33%	100%
3	Count		2	14	13	29
	Percent		7%	48%	45%	100%
4	Count			2	20	22
	Percent			9%	91%	100%
Total	Count	0	4	21	36	61
	Percent	0%	7%	34%	59%	100%

Table B14

f. Preparation to facilitate recognizing and responding to diverse student learning needs

		Follow-up Survey Rating				
Pre-program Rating		1	2	3	4	Total
1	Count	0		1		1
	Percent	0%		100%		100%
2	Count		3	6	4	13
	Percent		23%	46%	31%	100%
3	Count			18	10	28
	Percent			64%	36%	100%
4	Count			2	17	19
	Percent			10%	90%	100%
Total	Count	0	3	27	31	61
	Percent	0%	5%	44%	51%	100%

- **Science Teaching Practices.** Teachers were asked to indicate how often they use particular strategies in their science lessons on a 5-point scale, with 1 = Never, 2 = Rarely (a few times a year), 3 = Sometimes (once or twice a month), 4 = Often (once or twice a week), and 5 = All or almost all science lessons. Usage of six of the eight teaching practices rated in the survey increased. Teachers initially rated their usage of each practice between 3.0 and 4.0 on the average. In the follow-up survey the average for each practice was close to 4.0 except for the use of formal teacher presentations, which remained around 3.0. Summary results are given in Table C.

Table C

							Overall Mean		
		1	2	3	4	5	2004	2005	Change
a. Introduce content through formal teacher presentations	2004	8%	10%	42%	33%	7%	3.20	3.07	-0.1
	2005	3%	26%	36%	30%	5%			
b. Arrange seating to facilitate student discussion	2004	5%	11%	15%	36%	33%	3.80	3.95	0.2
	2005	3%	5%	20%	38%	34%			
c. Use open-ended questioning strategies	2004	3%	2%	25%	54%	16%	3.79	4.07	0.3*
	2005	3%	3%	10%	51%	33%			
d. Require students to explain their reasoning when giving answers	2004	3%	5%	25%	42%	25%	3.80	4.26	0.5*
	2005	2%	2%	6%	49%	41%			
e. Encourage students to communicate scientifically	2004	3%	12%	35%	38%	12%	3.43	4.07	0.6*
	2005	2%	2%	18%	47%	31%			
f. Encourage students to explore alternative methods for solutions	2004	5%	13%	34%	36%	12%	3.36	3.75	0.4*
	2005	2%	3%	30%	49%	16%			
g. Use assessment to find out what students know before or during a unit	2004	2%	15%	31%	39%	13%	3.48	3.82	0.38
	2005	2%	8%	21%	44%	25%			
h. Conduct systematic observation of student activities for the purpose of assessment	2004	7%	15%	25%	36%	17%	3.42	3.83	0.4*
	2005	2%	10%	20%	42%	26%			

*Statistically significant change from pre to post (alpha <= 0.05)

- **Student activities.** Teachers were asked to rate how often their students take part in particular activities as part of their science lessons on a 5-point scale, with 1 = Never, 2 = Rarely (a few times a year), 3 = Sometimes (once or twice a month), 4 = Often (once or twice a week), and 5 = All or almost all science lessons.

  Increased ratings were noted for seven of the twenty activities. They are listed below (numbers in parentheses are average follow-up rating and amount of increase):
  - Participate in discussion with the teacher to further science understanding (4.1, 0.4)
  - Write reflections in a notebook or journal (3.2, 0.4)
  - Write a description of a plan, procedures, or problem-solving process (3.1, 0.4)
  - Take tests requiring constructed responses (2.9, 0.3)
  - Design or implement their own investigation (2.8, 0.3)
  - Work in cooperative learning groups (4.2, 0.2)
  - Record, represent and /or analyze data (3.7, 0.2)

Two activities showed decreased ratings for the frequency of student participation (numbers in parentheses are average follow-up rating and amount of decrease):

- Take short-answer tests (e.g., multiple choice, true/false, fill-in-the blank (2.4, -0.3)
- Answer textbook/worksheet questions (2.2, -0.2)

Table D below provides detailed results.

Table D

							Overall Mean		
		1	2	3	4	5	2004	2005	Change
a. Participate in discussion with the teacher to further science understanding	2004	0%	10%	22%	52%	16%	3.72	4.14	0.4*
	2005	0%	0%	11%	66%	23%			
b. Work in cooperative learning groups	2004	0%	3%	23%	54%	20%	3.90	4.14	0.2*
	2005	0%	0%	20%	46%	34%			
c. Work independently	2004	2%	24%	46%	26%	2%	3.02	3.08	0.1
	2005	2%	20%	51%	24%	3%			
d. Read from a science textbook in class	2004	31%	35%	26%	5%	3%	2.15	2.08	-0.1
	2005	30%	39%	26%	3%	2%			
e. Answer textbook/ worksheet questions	2004	16%	38%	36%	7%	3%	2.43	2.18	-0.2*
	2005	28%	39%	23%	7%	3%			
f. Work on solving real-world problems	2004	5%	25%	47%	21%	2%	2.90	3.05	0.2
	2005	0%	28%	44%	23%	5%			
g. Share ideas or solve problems w/each other in small groups	2004	0%	8%	25%	52%	15%	3.74	3.93	0.2
	2005	0%	3%	20%	57%	20%			
h. Engage in hands-on science activities	2004	0%	5%	10%	65%	20%	4.00	4.16	0.2
	2005	0%	0%	11%	61%	28%			
i. Play science games	2004	17%	30%	36%	15%	2%	2.54	2.56	0.0
	2005	13%	36%	33%	18%	0%			
j. Follow specific instructions in activity or investigation	2004	2%	7%	38%	45%	8%	3.52	3.62	0.1
	2005	0%	5%	38%	49%	8%			
k. Design or implement their own investigations	2004	13%	41%	33%	13%	0%	2.46	2.77	0.3*
	2005	3%	33%	49%	13%	2%			
l. Work on extended science investigations/ project (week or more)	2004	11%	25%	33%	25%	6%	2.90	3.07	0.2
	2005	5%	21%	45%	21%	8%			
m. Record, represent and/or analyze data	2004	0%	7%	47%	39%	7%	3.46	3.69	0.2*
	2005	2%	7%	26%	52%	13%			
n. Write a description of a plan, procedures, or problem-solving process	2004	13%	26%	41%	17%	3%	2.70	3.11	0.4*
	2005	3%	26%	31%	35%	5%			
o. Write reflections in a notebook or journal	2004	10%	31%	33%	18%	8%	2.84	3.23	0.4*
	2005	12%	15%	26%	34%	13%			
p. Use computers for learning or practicing skills	2004	27%	21%	37%	15%	0%	2.37	2.49	0.1
	2005	20%	28%	37%	13%	2%			

Student activities continued . . .

q. Use computers as a tool (e.g., spread-sheets, data analysis	2004	41%	30%	20%	9%	0%	1.97	2.08	0.1
	2005	33%	34%	21%	10%	2%			
r. Take short-answer tests (e.g., multiple choice, true/false, fill-in-the-blank)	2004	15%	25%	34%	23%	3%	2.75	2.45	-0.3*
	2005	20%	34%	28%	18%	0%			
s. Take tests requiring constructed responses	2004	23%	20%	38%	16%	3%	2.57	2.90	0.3*
	2005	11%	20%	36%	33%	0%			
t. Engage in performance tasks for assessment purposes	2004	5%	20%	47%	28%	0%	2.98	3.11	0.1
	2005	7%	15%	44%	29%	5%			

- **Summary of Responses to Follow-up Interviews with Teachers Who Completed the *PET* Jr. Field Test.** In-service teachers who participated in the Summer 2004 workshops conducted by *PET* collaborators were interviewed about their use of *PET* Jr. as well as their use of what they learned in the summer workshop. Fifty-seven teachers were interviewed in Spring 2005. Below is a summary of their responses.

  - **About the *PET* Jr. Field Test Teachers.**
    - **Units field tested**

Magnetism or Magnets	*40%*
Force & Motion	*34%*
Light	*15%*
Electricity	*11%*

    - ***PET* Jr. unit compatibility with their curriculum**

Yes	*72%*
No	*16%*
Somewhat	*9%*
Yes and no	*2%*

    - **Topic taught as part of their science program**

Yes	*49%*
No	*35%*
Somewhat	*12%*
Unclear or no response	*4%*

  - **Have you used any of the other *PET* Jr. units or parts of units in your class this year?** [43 responses from 43 participants]

	BS	**F**	**I**	**SD**	**WW**	*Total*
No	3 (100%)	7 (58%)	5 (83%)	9 (100%)	11 (85%)	*35 (81%)*
Yes	--	5 (42%)	1 (17%)	--	1 (8%)	*7 (16%)*
No response	--	--	--	--	1 (8%)	*1 (2%)*
Total	*3*	*12*	*6*	*9*	*13*	*43*

- **How would you describe your familiarity with inquiry approach prior to the summer workshop?** [48 responses from 43 participants]

	BS	**F**	**I**	**SD**	**WW**	*Total*
I had no, little, or limited familiarity with the inquiry approach.	2 (50%)	2 (14%)	1 (14%)	--	5 (38%)	*10 (21%)*
I was familiar with the inquiry approach because I was using it in the classroom.	--	6 (43%)	1 (14%)	2 (20%)	--	*9 (19%)*
I was familiar or somewhat familiar with the inquiry approach because of my experiences with FOSS, STC/MC, or other inquiry-based science kits.	1 (25%)	2 (14%)	1 (14%)	1 (10%)	2 (15%)	*7 (15%)*
I had some familiarity with the inquiry approach.	--	--	--	3 (30%)	2 (15%)	*5 (10%)*
I was familiar with the inquiry approach because I attended trainings, classes, or workshops on it.	--	--	1 (14%)	2 (20%)	1 (8%)	*4 (8%)*
I was familiar with the inquiry approach but I wasn't using it.	--	1 (7%)	2 (29%)	--	1 (8%)	*4 (8%)*
I was familiar or very familiar with the inquiry approach [no further clarification was given].	--	1 (7%)	1 (14%)	1 (10%)	--	*3 (6%)*
I was familiar with the inquiry approach because my district was pushing it or becoming familiar with it.	1 (25%)	1 (7%)	--	--	--	*2 (4%)*
I was familiar with the inquiry approach because I had a strong background in it.	--	1 (7%)	--	1 (10%)	--	*2 (4%)*
I did not understand inquiry.	--	--	--	--	2 (15%)	*2 (4%)*
Total responses	*4*	*14*	*7*	*10*	*13*	*48*

- **Were you using inquiry before the summer workshop?** [43 responses from 43 participants]

	BS	**F**	**I**	**SD**	**WW**	*Total*
Yes	1 (33%)	5 (42%)	2 (33%)	7 (78%)	2 (15%)	*17 (40%)*
No	2 (67%)	5 (42%)	2 (33%)	--	5 (38%)	*14 (33%)*
Somewhat, off and on, or a little bit	--	1 (8%)	2 (33%)	2 (22%)	1 (8%)	*6 (14%)*
Not to the current extent	--	--	--	--	3 (23%)	*3 (7%)*
Kind of	--	--	--	--	1 (8%)	*1 (2%)*
Trying to	--	--	--	--	1 (8%)	*1 (2%)*
No response	--	1 (8%)	--	--	--	*1 (2%)*
Total	*3*	*12*	*6*	*9*	*13*	*43*

- **Strongest Aspects of the *PET* Jr. Materials.** When participants were asked what they thought were the strongest aspects of the *PET* Jr. materials, three aspects were most frequently identified: the organization of the materials, the constructivist nature of the materials, and the information that helped teachers know what to expect from the students. 31 out of 57 (54%) teachers identified the organization of the materials as a strength, with comments about the way the lessons were put together, how smoothly they worked, and how "teacher-friendly" they were. One said, *"There was a process to the lessons. The different components of the lessons are clear, concise, not wordy, easy to understand and teacher-friendly. You could pick it up and use it."*

Twenty-seven (47%) of the teachers indicated that one of the strongest aspects of the materials is that they support inquiry-based learning, with hands-on lessons, where students learn by discovery and are allowed to construct their own meaning. One teacher described it this way, *"This is classic constructivism…hands-on, very sequential, it builds on prior knowledge."* Another teacher appreciated how the students *"explore the ideas before being told about them."*

Nineteen (33%) of the participants found the information provided to teachers about what to expect from the students, including the kinds of questions students might ask and the misconceptions they might have, to be a strength. One teacher talked about *"the piece about what ideas to expect from the kids…they held true and helped her know what to expect."* Another commented that she *"liked the 'what to expect' piece because it prepared her for misconceptions. It was also right on."*

Among the other responses to this question, 18% of participants indicated they liked the way the lessons were framed around the "big questions," commenting that it was valuable for students to start with questions and seek the answers. Several participants (14%) mentioned the activities themselves, noting students enjoyed them and they held the students' interest; 14% mentioned the usefulness of having students make predictions; 9% identified the "Big Ideas;" and 9% identified the group work. Other aspects identified included the consensus at the end to show what the students know, the use of white boards, simulators, and worksheets, and the way the materials were aligned with the curriculum.

- **Weakest Aspects of the Program.** Participating teachers were asked to identify the weakest aspects of the program. While there were no outstanding weaknesses reported by a majority of teachers, there were concerns and suggestions for improvement offered.

  Among the aspects of the program identified as weaknesses, again three categories stood out. Interestingly, the most frequently identified "weak" aspect of the program (11 out of 57, 19%) was the same as the most frequently mentioned "strong" aspect of the program—the organization of the materials. This category included comments about problems with the organization of specific lessons and directions that were missing key details. One teacher stated: *"The lessons on the disk were not very well organized. She had to go to multiple folders to find the hand-outs, lessons, etc. for the first lesson."* Another teacher gave a description of problems she ran into: "*The procedures aren't clear. Some very important things have been left out, and if you didn't do it yourself you would be in trouble. For example, in the lesson with the overhead projector and the circle of light, you had to make sure the circle of light is lined up with the students' eyes or it wouldn't work. That wasn't mentioned in the lesson. . . . Also, there was a question that says, 'Who is able to see the light?' in one of the lessons. But she wasn't sure what light they were talking about…the flashlight, the light from the mirror, or the light off the paper. That needs to be clarified."*

  The second most frequently mentioned weakness (18%) was that the lessons had to be adapted for older or younger children. In some cases adaptations were necessary to satisfy school requirements. One participant who teachers 7th and 8th grade students stated she had to make adjustments such as using lab journals, doing more assessment, and making up questions to match the questions on standardized science tests her students would be taking that year. Another teacher noted *"It wasn't geared toward the younger grades. She had to make a lot of adjustments because some concepts were too hard for her students to grasp."* A kindergarten teacher commented that some of her students had limited language and could not tell what they were thinking, so the teacher had to use nonverbal cues. Another teacher commented that while she had to modify the lesson for her young students, she did not see that as a particular weakness, since “teachers need to modify lessons all the time.”

The third category of weakness, identified by 14% of the participants, was the need or desire for more training and preparation for teachers. In some cases teachers found the inquiry-based pedagogy a challenge. In other cases they wished for more content knowledge. In representative comments, one teacher said she wasn’t sure *“how to illicit good questions or responses”* from her students, so she would like more sample questions for the teacher. Another said, *“Both she and her students still have questions. She would like more teacher background knowledge, like where do magnets really come from, besides ‘the ground.’”*

Other identified weak aspects of the program included difficulties in acquiring or finding the necessary materials (9%); the cost of the materials (9%) the lessons require more time to complete than is available in 45 minute class periods (9%); and the teaching style is challenging, e.g., it is difficult to leave the students struggling with a partial understanding of a concept (7%). Others commented that there should be more writing involved; there should be more assessments; the experiments are too easy or not as interesting as they could be; there is too much paper use; supplementing materials were required; more vocabulary was needed; and the cars were “too fun” and distracting for the students.

Among the remaining responses, 12% indicated they saw no weakness. One teacher’s comments illustrate this finding: *“None. The students responded positively. They were more excited about learning [this] than any other topic. . . . No adaptation was needed. At first the teacher felt like some of the materials were above the students’ grade level, but they understood them.”*

Specific suggestions for improvements are listed below:

- At the end of the magnet unit make a toy or a Lego car using magnets where they could apply what they have learned.
- In magnet lesson, creating a stronger magnet was given as a content goal but was never explained in the lesson. Also should mention that bar and wand magnets can be used with very similar results.
- In Force and Motion Lesson 3, smooth track was not defined. Teachers who have not been to the workshop may not know what is needed. Suggests having students do trials and have them find the average, have them measure in centimeters. Also suggests indicating in the lesson which activities need more space so teachers can plan to work in a larger room.
- Requests specific explanations and answers provided for the teacher to make sure the students are not walking away with misconceptions.
- For 8th grade students you need data sheets for students to fill out so that they are accountable.
- More paragraph writing.
- Need pre- and post-assessment. Suggests a portfolio.
- The placement of questions could be improved. The kids would do the experiment and then come back to the question.
- Needs to be less paper for teacher to copy when teachers have a large class. Perhaps store the information on overheads or PowerPoint.
- Identify the questions in the lesson more clearly, with numbers, bold font, special heading, or some easy way to refer to them quickly. Also need a space that says “Student Response” so that teachers pause and let students talk. Also highlight “Purpose” so teacher sees it readily.
- Suggest more experiences about light traveling in a straight line to get the idea across. Suggests investigation of different materials and light, like what materials can reflect, block, are transparent.
- Need proofreading and clarification on the units. Material list in Activity 3 (magnets) was confusing; some things were repeated and others were not clear. It said the magnets should have colored ends, his materials didn’t have colored ends and he wasn’t sure if each pole was supposed to be a different color.
- A 90 minute unit actually takes 3 or 4 periods in school. Would suggest future workshops set up in 45 minute chunks so that teachers can get a better idea of how it really works.

  - More scientific background for teachers in the units.
  - Suggests dialogue box (as in TERC) which has a sample conversation between teacher and student and student to student.
  - More detail on procedures in the lessons, what to do with objects, what the teacher is supposed to do.
  - What to do when students don't reach the Big Idea at the end of the lesson?
  - Suggests more depth to lessons.
  - Suggest a lesson with buzzer and battery alone so students can investigate those and switches more.

- **Summer Workshop – Changed Beliefs.** Participants were asked whether their beliefs about teaching and learning of science had been changed in any way by the summer workshop. 47 (82%) of the participants responded positively, while 10 (18%) said that their beliefs had not changed.

  Among those whose beliefs had been changed, 25 (44%) indicated that they had come to believe that hands-on, inquiry-based teaching and learning "really is better" than directed, book-based teaching and learning. One teacher stated she *"already knew that children learn by doing. However, she taught the way she had been taught—by the book. She now tries more hands-on activities."* Another teacher said she is *"now using inquiry approaches throughout reading, writing, and social studies…and the science textbook has not been used very much during the school year."*

  Ten (18%) of the teachers reported that they had come to understand that it is important to be aware of students' preconceptions and misconceptions in the teaching process. Similarly, 8 (14%) reported they had come to understand that it is important for teachers to be aware of their own misconceptions. As one teacher described it, *"she has become aware of the power of what you think and why, the power of correcting your own mistakes and why that is powerful."*

  Ten (18%) of the teachers indicated that their beliefs were changed about use of questioning strategies and intentionally not giving answers. One teacher said she *"learned the importance of questioning and self-discovery."* Another had come to appreciate that, *"there is an art to asking questions, when and how to do it."* Six (10%) of the teachers indicated that they had previously had negative feelings about science or physics, but now their feelings were positive. As one teacher described it, *"In junior high and high school she felt like she wasn't good at science. She didn't understand it. It was taught out of the book through lecture. The negative feelings toward science stuck with her and were starting to carry over to her teaching. During the workshop she was forced to figure things out herself and she realized she could do it."*

  Other ways in which teachers reported their beliefs about teaching and learning science were changed included: that inquiry learning can be directed or guided; what it is like to be in the student's place; that teachers can teach this successfully; the significance of identifying evidence and proof ; the importance of group or collaborative work; a change in the teacher's perspective on the world, shifting to "thinking like a scientist;" that children can learn this successfully; the usefulness of making predictions; the usefulness of the Big Ideas; and the usefulness of white boards.

- **Summer Workshop – What Was Learned.** Participants were also asked to identify two or three things they had learned from the workshop about science, scientific thinking, or the processes of science. The majority (65%) responded that they had learned about the techniques and usefulness of inquiry-based teaching and learning of science, including using investigation and exploration, hands-on learning, not giving answers, the process of making predictions and searching for answers, and supporting findings with evidence. One teacher said, *"Science can be* *powerful when you develop your own understanding of it, and so much can be gained through exploration."* Another said simply, *"Hands-on works best."* Yet another stated, *"In order to believe in a scientific principle you need to feel, do, look, explore the event. All modalities need to be involved."*

About 32% of the teachers stated they had learned about the significance of misconceptions, both students' and teachers'. One teacher said she learned *"how deep misconceptions are rooted into people. During the summer workshop people would keep going back to their misconceptions. It is difficult to remove their misconceptions."* About 30% of the teachers reported they had improved their understanding of content. One teacher commented that she had gotten a deeper understanding of physics concepts. Another reported she had *"avoided physics since the 8th grade. Now she could finally see how things worked. It was exciting to be the learner and discover on your own."*

About 19% of the teachers learned about the importance of collaboration and group work. One teacher commented that *"Students need to work together and learn from their peers."* Another stated, *"Teach children how to take turns, listen to each other's ideas, and share their ideas. A science classroom should not be quiet."* About 14% of the teachers noted they learned about the scientific process and that it is "not what we think." One teacher said, *"Science is not done the way we are taught. Scientists don't make a hypothesis, etc. Real science doesn't work that way…You make an observation, form a question, and go from there."* Another said, *"Science is a process, not a strict order. Scientists are just like us; they have observations, come up with ideas, and test their ideas."* 12% of the teachers reported they had learned about the usefulness of white boards for sharing ideas and having the students share what they are thinking.

Other comments from participants about what they had learned included that science and physics can be fun, it does not have to be intimidating, and anyone can do it; that time is needed for reflection and discussion; that students, like all people, have different points of view; and that inquiry science can be frustrating.

- **Other Ways the Summer Workshop Influenced Participants' Teaching.** The teachers were asked in what ways, in addition to using the *PET* Jr. materials in their classrooms, the summer workshop had influenced their thinking. A majority, 68%, reported that the workshop had influenced their understanding of the value of inquiry-based teaching and to use it in other areas. One teacher reported she is now *"using the inquiry process, talking about previous knowledge, and making predictions across the curriculum."* Another reported she *"gives students a chance to investigate topics in all subject areas."* Another teacher described a change in her teaching style this way: *"In social studies while studying Black history she asked the question, 'What would it feel like if you couldn't go in the library because of your race?' The next day she had the kids take a card that said 'Black' or 'White,' and they did a simulation based on it. They had to investigate the problem and talk about it. It would have been easy to read a book about Rosa Parks and tell the students that Black people didn't like being discriminated against, but she did inquiry teaching."*

  About 35% of the teachers reported that they had been inspired to evaluate their own teaching styles and attitudes, several indicating they had become more confident or gained more pleasure in teaching science. One teacher reported the workshop made her *"more aware and open minded to science. It is less scary to teach."* Another teacher said she has *"realized that science is fun."* Another teacher said he *"has more enthusiasm in other subject areas…He wants to go above and beyond…"* There was a teacher who commented that she is *"more careful in presenting concepts, doesn't want to present any misconceptions."* Still another stated he is *"more passionate about* *trying to educate elementary teachers and trying to stop the misconceptions that are being taught."*

About 30% of the teachers reported they gained a better understanding in general of what students can do, what their experience is like, and how they learn best. One teacher commented that she realized, *"how much kids can do themselves; they just need to be given the big ideas."* Another teacher reports, *"Kids are naturally inquisitive. If they are given an interesting problem they will use their prior knowledge, try to figure it out and discuss their ideas with their peers."* Another said she had learned *"how to reach different levels of kids—how to extend concepts for kids who really understood a concept and how to support kids who were struggling."* One teacher described it this way, *"Kids ask questions if they don't understand. I don't like to give the answer but point them in the right direction. When they find something out on their own they understand it better and retain the information better."*

14% of the teachers reported they had been inspired to check for students' preconceptions and misconceptions. 10% had been inspired to use white boards in science or other areas. 10% reported they had changed their questioning techniques. 9% said they had been inspired to have students work more in groups. Other changes included more teacher networking; having students make more predictions; and asking for evidence.

- **Summary of Responses to End-of-Summer Workshop Evaluation Questionnaire: Perceptions of the Workshop.** At the end of the teacher workshops, participants were asked to complete an evaluation questionnaire about their perceptions of and satisfaction with the workshop. Below is a summary of mean ratings across the five workshops.

  - **Workshop Objectives.** Participants were asked to rate MAJOR SESSION OBJECTIVES according to 1) their perception of the ***value*** of the objective and 2) whether they thought the objective was ***accomplished*** during the session on a 5-point scale, with 1 = low and 5 = high. V = value; A = accomplishment. The table below shows mean score ratings for each of the workshop sites.

Workshop Objectives	Mean Ratings					
		Site 1	Site 2	Site 3	Site 4	Site 5
1. To learn physical science concepts related to the cycles covered in the workshop	V	4.60	4.81	4.88	4.45	4.62
	A	4.00	4.76	4.76	4.25	4.28
2. To learn how to recognize and analyze your own ideas, your peers' ideas, and Elementary Students' Ideas about physics	V	4.60	5.00	4.88	4.61	4.56
	A	4.30	4.95	4.76	4.19	4.42
3. To learn how students' ideas (including your own) develop and change over time	V	4.60	4.95	4.94	4.58	4.64
	A	4.40	4.86	4.82	4.31	4.28
4. To learn how to apply what you have learned in the *PET* workshop to your own classroom instruction (e.g., *PET* Jr. activities)	V	4.30	4.57	4.94	4.64	4.38
	A	3.60	4.33	4.88	3.94	3.16
5. To learn about the nature of science knowledge including the role of evidence, consensus, and creativity	V	4.20	4.67	4.65	4.36	4.23
	A	3.90	4.67	4.59	4.13	4.23
6. To understand that the learning environment and curriculum impact the development of student ideas	V	4.80	4.90	4.82	4.58	4.51
	A	4.70	4.86	4.82	4.38	4.36

- **Workshop Procedures/Activities.** Teachers were asked to rate a series of procedures and activities that were used in the workshop on how useful they were in helping them understand the physical science concepts studied in the workshop on a 5-point scale, with 1 = Not useful and 5 = Very useful. The table below shows mean ratings across workshops sites.

Procedures/Activities Used in Workshop	Mean Ratings				
	Site 1	Site 2	Site 3	Site 4	Site 5
1. Knowing the Key Question to be answered by an activity or experiment	4.70	4.62	4.53	3.94	4.35
2. Conducting the experiments and other hands-on activities	5.00	5.00	5.00	4.88	4.90
3. Working in teams	4.90	4.81	4.88	4.52	4.62
4. Making claims based on evidence	4.78	4.86	4.94	4.76	4.64
5. Developing consensus ideas	4.80	4.57	4.88	4.42	4.05
6. Printed activity sheets	4.50	4.74	5.00	4.06	4.13
7. Computer-based simulator activities	4.90	4.76	5.00	4.52	4.33
8. Computer-based motion detector activities	5.00	4.81	4.94	4.73	4.56
9. ESI materials/resources and activities	4.50	4.67	4.59	3.93	4.26
10. Whole class summarizing discussions	4.20	4.76	4.88	4.21	4.44
11. Scientists' ideas	4.50	4.57	4.65	4.18	4.36
12. Sharing and discussing your initial ideas at the beginning of activities	4.40	4.90	4.59	4.00	4.51

- **Workshop Facilitation.** Participants were asked to rate several items related to the implementation of the workshop on a 5-point scale, with 1 = Disagree and 5 = Agree. The table below shows mean ratings across workshop sites.

Workshop Facilitation	Mean Ratings				
	Site 1	Site 2	Site 3	Site 4	Site 5
1. The workshop was well organized.	4.70	4.95	5.00	4.55	4.79
2. Workshop leaders were effective in organizing sessions so that I was actively involved.	4.80	5.00	5.00	4.42	4.61
3. The overall pace of the workshop was appropriate.	4.40	4.71	4.94	3.61	3.95
4. Workshop details provided prior to the session were useful.	4.11	4.67	4.76	3.61	3.86
5. A collaborative and helpful tone was established during the workshop.	5.00	4.90	5.00	4.73	4.67

EVALUATION FINDINGS: *Users of Published PET Materials*

The Physics of Everyday Thinking (*PET*) materials development project has resulted in a comprehensive set of printed, digital, and on-line college-level course materials; corresponding materials for use in elementary classrooms; and professional development resources for college instructors on the use of the *PET* curriculum. The materials are now available through *It's About Time* Publishing.

As part of the external evaluation of *PET*, telephone interviews were conducted in November 2006 with faculty from around the country using *PET* materials in their courses. The purpose of the interviews was to learn about why the *PET* materials were chosen, how they were being used, strengths and limitations of the materials, students' responses to the curriculum, and suggestions for improvements.

Evaluators were provided with 20 names and contact information of faculty who had purchased *PET* materials. All were using the final version of *PET* in their classrooms. Of the 20 faculty, 16 were interviewed (four could not be reached).

- **Profile of Interviewees**. All are faculty members at one of the following institutions: Buffalo State University, East Tennessee State University, Jamestown Community College (New York), North Harris College (Texas), Purdue University, Rockhurst University (Kansas), Southeast Louisiana State University, Tennessee Technological University, University of Arkansas, University of Colorado—Boulder, University of Michigan—Dearborn, University of Minnesota, University of Wisconsin—Whitewater.

  PET was used in the following classes:

Interviewee	Classes Using *PET*	Course Audience	Number of Students
1	Science Education (new course)	Elementary pre-service plus some graduate students	5 sections per year ~ 140 students
2	Elementary Physics	Non-science majors including pre-service elementary	2 sections per year ~ 32 students
3	Master's level summer classes: Physical science for elementary and middle school teachers	Master's students in elementary and middle school education programs	1 section per summer ~ 10 students
4	Physics 1310 (basic physics)	Primarily elementary education majors	3 sections per year ~ 90 students
5	Physics for Elementary Teachers	Elementary education majors	1 section per year ~ 24 students
6	Physics for Elementary Teachers	Elementary education majors	1 section per year ~ 20 students
7	Title II Improving Teacher Quality Grant Project	In-service elementary teachers	1 summer program ~ 40 participants
8	Physical Science	Elementary education majors	5 sections per year ~ 96 students
9	Physics for Elementary Teachers	Elementary education majors	4 sections per year ~112 students
10	Physics for Elementary Teachers	Elementary education majors	2 sections (lecture/lab) per year ~ 200 students

Profile of interviewees continued . . .

11	Physics for Elementary Teachers	Elementary education majors	1 section per year ~ 15 students
12	Physics 142 (basic physics)	Elementary education majors	5 sections per year ~ 150 students
13	Physics for Elementary Teachers	Elementary education majors	4 sections per year ~ 128 students
14	Physics for Elementary Teachers	Elementary education majors; some other non-majors	2 sections per year ~ 64 students
15	Understanding Physics	Early childhood education majors; elementary education majors; communications majors	1 section per year ~ 20 students
16	Basic Physics	Pre-service elementary teachers	2 sections per year ~ 48 students

Of the sixteen interviewees, 8 indicated that one or more other faculty members in their departments also taught the *PET* curriculum in the same courses.

- **Summary of Responses to Interview Questions.** During the 30-minute interview, *PET* users were asked to respond to 10 questions. What follows is a synthesis of responses to each question.

  - **Why *PET* Materials Were Chosen.** When participants were asked why they decided to use the *PET* materials, about half reported that they had been looking for a new program or were not satisfied with the program they were using. They found *PET* had characteristics they had been looking for, such as inquiry-based and hands-on learning, an emphasis on learning about learning, and a focus on conceptual learning. One respondent said, *"I liked that it was guided inquiry. I prefer depth instead of breadth, and it is research-based and I like that."* Several report they had been looking at developing their own courses and were glad not to have to "reinvent the wheel." One respondent states he had just been asked to design a course to meet new requirements when he saw a presentation on *PET*: *"This is perfect. It's set up, I can follow it. It's very hands-on, student-oriented, and very much in the dialogue-type method of teaching. I could see the value in it immediately. I loved it as soon as I saw it. Also the videos of the kids working with the physics materials, where the students analyze the children's videos of learning physics, were really the icing on the cake."*

    Several individuals report that someone from their institution had attended a workshop that included a presentation on the *PET* curriculum, and that had inspired them to use it. Three indicated that they were using it because their faculty had been involved in developing it. Two respondents indicated that they had chosen it partly because its content meets state requirements. One interviewee provided a typical comment: *"We were looking for a curriculum at the time that the elementary majors could tolerate because they hated everything that we had tried…I had tried 2-3 different curricula and we still were not making a lot of progress…I contacted [*PET *developer] and he was running a training program that summer. We adopted it for the next semester. Literally I heard about it in August and we had it going in September."*

  - **Plans for Future Use of *PET*.** When asked what their plans are for the use of *PET* materials in the future, all respondents indicated that they plan to continue to use the *PET* materials. One reports that the course is *"actually easier to teach than the regular course because I don't have to* *talk so much, I'm not the face on the stage."* Another said, *"I intend to continue using these materials for this particular population until something better comes along or the sky falls."* A few report that they may switch to PSET or augment *PET* with PSET, citing a need for incorporating chemistry. A few respondents report that they will augment *PET* with materials from other curricula. One interviewee who states she did not have a chance to become fully prepared for the *PET* program before using it, reports she hopes to get fully up to speed and continue with *PET*. Another respondent is concerned about institutional pressure to increase class size beyond a practical size for the *PET* program, but indicates that for the near future, the plan is to continue with it.

- **Following *PET* Cycles as Specified in the Program**. When asked about whether they had followed the *PET* cycles as they are specified in the program, three of the seventeen respondents stated that they followed the program just as written, with no additions or deletions. One of them responded this way: *"I just use everything. I have used another inquiry style type of course and I love this one. I have no intentions of changing this one."*

  Thirteen of the respondents indicated that they had primarily followed the cycles as provided. Four of those supplemented the curriculum with some additions, five modified with some deletions, and three modified with both additions and deletions. Those who chose to supplement the *PET* curriculum with additional content report specifically that they added materials on static electricity, color, energy, and the environment. One supplemented with PHEP simulators. One added a supplemental textbook for reference purposes. A few state that they pulled from CPU activities, other textbooks, the Internet, and/or videos to augment the *PET* materials, usually by adding lectures or demonstrations. A few added *PET* Junior activities, writing assignments, or research papers. One respondent reports, *"At the end of the course we require them to find some children, teach them some of the PET Junior activities that are related to the topics we covered that semester, write a 3-page reflective article on it, and try to weave in a couple of references from science literature."*

  The respondents who reported they had deleted portions of the *PET* curriculum stated almost universally that the reason for the deletions was shortage of time. A few of these report that they cut Cycle 7 short or had to delete it altogether. As one interviewee describes it, the last cycle can be hard to get to: *"I touched on it, but we didn't get to spend a whole lot of time on it. It seems that no matter what I do, we always go more slowly than I think we will."* Another respondent reports deleting the sections on motors and electro-magnetism. One deleted Cycle 6, reporting this was on the advice of the developers. Another deleted Cycle 6 one year and parts of Cycles 3 and 5 another. Another stopped Cycle 5 after Activity 2, skipped Cycle 6, Activities 1, 3, 4, 5, and then did as much of Cycle 7 as possible. One respondent, whose population was not primarily elementary education teachers, skipped the elementary student reading and activities, although she states she keeps the Elementary Students' Ideas *"because it really matches their[college students] ideas too"* and alerts the future teachers in the class about the materials she has skipped. Another found the refraction materials confusing to students and deleted that section when short on time. One respondent reports omitting a section on the scientific method, *"partly to save time, but partly because I had a disagreement as to whether that [the emphasis on how science is done in groups] was the most important thing to say about the scientific method."*

  One participant describes being responsible for creating a new 120-hour "best practices in science content course" with a 4-hour lab. New to *PET* and unfamiliar with it, she describes "picking and choosing" portions of the *PET* curriculum and adding some material from old textbooks and from the Internet. She states that she decided on the order of cycles by what made sense to her: *"I decided that I can't even begin to go into Newton's laws until they understand what speed is and* *what velocity is and what acceleration and force is. I did all those first, and then I would do Newton's first law and then Newton's second law."* She added, *"I do experimental design throughout, I do nature of science throughout, and I like that this book addresses that."* She reports that she consistently used the pedagogical strategies in the curriculum, including small group work, but did not use the ESIs, simulations, or Scientists' Ideas.

- **Using Intended Instructional Strategies.** When asked whether they had used the intended instructional strategies outlined in the curriculum, including inquiry-based, open-ended questioning, small group work, and computer-supported activities, the participants universally responded positively that they had used them. A few indicated that they adjusted the strategies slightly, such as spending more or less time on particular activities or breaking them down into smaller units. One notes that she refines the strategy for group work by doing team building first, *"so they have to learn to work in groups and it's not just putting kids together."*

- **Simulations, Homework, ESIs, Scientist Ideas.** When asked if they had used the computer simulations, homework assignments, Elementary Students' Ideas (ESIs), or Scientists' Ideas, all but one of the respondents said that they had. A few use some but not all of the ESIs. One respondent finds special value in the ESIs: *"I think the ESIs actually serve a real important purpose. I explain to the students whether you are an education major or not it teaches you to listen to somebody else explaining something, even if it's a child (that doesn't make any difference), it's just that you have to listen and decide what you are hearing so you can respond to them, and that is an important thing for all of us to learn."* A few mentioned using Scientists' Ideas as the summary at the end of the chapter. One reports he has students compare their own answers to the Scientists' Ideas to make sure they are consistent.

  Again, a few respondents indicated that they adjusted the assignments slightly to fit their schedules and programs. For example, one interviewee reports that he discusses the Scientists' Ideas in a lecture/discussion format: *"We spend a lot more time with those and it probably looks a little bit different than what was intended."* Another reported she breaks up the activities differently, commenting, *"I think a little bit differently than [the PET developer] does. Rather than giving the students 50 minutes, I break down each activity into each of the little components and I give them an appropriate amount of time for each experiment, and then we have a 2-minute debrief at the end of each experiment so that all students are staying on task and I'm controlling the pacing instead of allowing the students to control the pacing."*

- **Electronic Faculty and Student Resource Materials.** Interviewees were asked in what ways they had used the computer-based faculty and student resource materials. All but one responded that they used the student resources, such as simulations, videos, and homework, as intended. One respondent remarked, *"We used it in every way we could…we go through the curriculum exactly the way it was designed."* A few noted that students appreciated doing their homework on a CD and emailing it to the instructor. A few also noted occasional problems with access to the Web materials, however they report downloading the materials to CDs solved those problems.

  All but two of the respondents report using the faculty resources as well. One respondent states, *"I love the resources being online. I just follow it perfectly."* Another stated, *"I love the pedagogy things that are in there."* Several use the teachers' guide, timeline, and outlines. One interviewee reports that she uses the online teacher's guide every day to prepare for class. Several report downloading the questions and keys for exams. A typical comment about the usefulness of the resources was, *"There are some nifty things in there, like tricks regarding* *setting up the apparatus. I have graduate students who work with me and it's really helpful for them. It's also nice to have a central repository of stuff updated from [the developer] that's so convenient."* Of the two respondents who do not use the faculty resources, one states she has not had time to explore them, and the other was involved in the development of the program and is familiar with them.

- **Strengths of the *PET* Materials.** When asked what they considered the strengths of the *PET* materials, the most frequently cited strengths related to the pedagogy of the curriculum. Most of the interviewees commented on its constructivist, inquiry-based, hands-on approach that supports a sequencing of concepts, uses the instructor as facilitator, and gets students thinking for themselves and working with other students. As one individual states, *"That is obvious. The students are actually doing physics with their own hands."* Another respondent points out that the pedagogy models a desirable pedagogy for the elementary classroom.

  Several respondents identified specific elements of the *PET* program as strengths. They mentioned the simulations, ESIs, Scientific Ideas, reflective writing, and videos. For example, one participant states: *"Exposing the students to the children's ideas and having them analyze them really works well for this group of students. It both motivates them and illustrates to them that they are thinking about things in the same way that their future students do. They really come around."* Two respondents appreciate that the materials assist the instructor with anticipating student errors and examining preconceptions.

  The next most frequently cited strength was related to the design of the curriculum. Again, over half of the respondents commented on ways in which the curriculum is well-crafted. They cited its coherence, the continuity provided by the unifying themes of energy and force, the building of concepts, and the built-in "revisiting" of important concepts in multiple ways. Two of the respondents specifically stated appreciation that the curriculum was designed based on knowledge about how people learn.

  Similarly, several respondents identified the content of the curriculum as a strength. As one interviewee notes, it focuses on "big picture" concepts and avoids "getting lost in equations." Another commented on the curriculum's coverage of "real" or mainstream physics. Two appreciated that it teaches about the nature of science, scientific inquiry, and evidence-based decision-making. One points out that the curriculum is aligned with national standards and recommendations.

  Finally, several respondents note the effects of the *PET* program on the students. They report that it ties in well with the interest and ability level of the students, it is relevant for them, and they tend to come out of the class feeling confident about their ability to "do" and teach science. As one respondent describes it, *"Students start to believe that they can do science, and these are students that are quite convinced that they can't. I had one student say, 'I'm not as stupid as I thought I was.' It's a really liberating thing for the students, and it's obviously totally important for anyone who wants to be an elementary teacher."* In addition, two respondents commented that it is a popular class which most students find worthwhile. One stated, *"We have anonymous assessments at the end of each of our classes, and there are very few students who have been anything but positive about all of this."*

- **Limitations of the *PET* Materials.** When the interviewees were asked about the limitations of the *PET* materials, there were no concerns mentioned consistently. The most frequently cited limitation was the lack of mathematics, noted by three interviewees. Similarly, two interviewees mentioned the lack of chemistry in the program. Two indicated that *PET* sacrifices depth for breadth “very slightly,” especially in the area of electric current, static electricity, and light. One said students have a difficult time understanding magnetism.

Other comments addressed the text and other materials. One respondent noted the *PET* language is not universal in physics. Another found that the content was not difficult enough. Two interviewees mentioned the repetition in the book as a limitation. Others commented that there are typos and oversights in the book and on the website and that some of the exam keys are misleading. A few mentioned technical difficulties, including problems with the visual portion of the videos and problems with accessing the website. One respondent commented, *“I mean seriously, we have schools with dialup and we have schools where the secretaries are the only ones who know anything and, bless their hearts, they can’t even get their email half the days.”* One mentioned students’ resistance to the writing required in the workbook. Another commented that the program does not set students up with a curriculum and materials all ready to use in their elementary classrooms. Another interviewee noted that the title of the book is misleading because the course in which *PET* is used is not always exclusively for elementary education students, but others may avoid it when they see that title. One respondent found the ESIs too advanced for the students.

A few more general limitations were identified. Two respondents noted difficulty fitting the complete program into the time they have available. One states, *“You can’t cover nearly as much material this way; if I were lecturing, I would be able to zip through Newton’s laws in say 6 lectures, but you can’t do that in an inquiry-based class.”* Another notes that is it hard for the instructor not to “fall into” lecturing. Another noted students’ resistance to taking responsibility for their own learning. One found the group work to be limiting because the groups work at different paces. Two expressed a need for more training and ongoing assistance in the form of supplementary materials addressing “what do you do with this in the classroom?”

- **Student Response to the *PET* Materials and Methods and Student Learning.** When asked about student response to the *PET* materials and methods, the interviewees overwhelmingly responded that student response was very positive. Several commented that this is a very popular class and they have waiting lists for it. One participant reports: *“I have looked very carefully at both my own student evaluations and at those of the adjunct who taught it a year ago, and for him 22 out of 23 students gave him the highest marks overall in everything about his teaching, and what they said about the course was that they liked the hands-on activities, they felt that the learning environment facilitated their learning, they liked the experiments, they liked sharing ideas with others, they liked both working on their own and working in groups, they very much liked the fact that having an inquiry-based book gave them a model for inquiry teaching, and they liked the technology and simulations.”* Another respondent reports, *“The student course questionnaires that come back get the highest ranking on every dimension for this course.”*

  One respondent pointed out that the class serves a population that tends to avoid science, stating: *“You know you’ve got a very special audience here. You’ve got elementary pre-service teachers and historically this population does not like science and especially does not like this particular branch of science. I’ve had students try to get out of it. They say, ‘Well, you know I took physical science back in community college.’”* But with the *PET* program, *“once they get it, yes, they do like it; they feel like they have learned something.”* Similarly, another person commented that many students are fearful about physics, *“but this class is not scary because of the lack of math.”* Yet another respondent has observed that fewer students drop this course than the equivalent regular physics course.

Some of the specific comments included that students like the way the *PET* program builds concepts, they like the hands-on activities, and they report when they go on as elementary teachers that their students also enjoy the methods. On the negative side, two respondents commented that some students do not like working in groups, especially because of pacing issues, and some students become bored. Another noted that students complain about the repetition in the program.

While they agree overwhelmingly that students enjoy the *PET* program, the interviewees also agree that students are often challenged by the style of teaching and learning in the program, with its open-ended questions, predictions, instructor as facilitator, and avoidance of providing "answers." One respondent reflected the comments of several when stating that a minority of students do not like the *PET* format, but by the end of the term most students feel empowered by it. Another stated that initially there is resistance to the course format, but *"it only takes about three weeks for them to get into it."* Yet another reported observing three groups of responses: 1) students who simply want to learn and do well respond well to the program; 2) students who have studied physics before and are expecting the course to be easy are typically surprised that it is challenging; and 3) students who are impatient with the reasoning process resist the format. One respondent reports a different experience than most, stating a minority of the students took to the course, while a majority objected to the format and wanted the instructor as the authority.

When asked about the students' learning of the science concepts using this program, again the interviewees responded positively. Several report that the students are learning more, and learning the concepts at a higher level, than they do in other physics courses. One respondent gives the example of how the students gain an understanding of energy transfer: *"By the end, no matter how complicated their energy diagrams are, they are whipping right through them and saying, 'Yeah, where's it coming from, where's it going, how'd it get there, what happened, what transformations occurred.' They are comfortable with the idea, and they buy into the idea, and it makes sense to them, and I don't think we can ask for a whole lot more than that."* Similarly, several respondents state that they can cover more in a regular lecture class, but the *PET* students end up with a better understanding. One described it this way: *"Like I said, you can cover more material when you are just standing there lecturing, but it is obvious when you talk to the students afterwards that folks in the* PET *class typically seem to have a much better understanding of the subject that you just covered, compared to the students in the big lecture class."*

Three respondents indicated concern with the assessments available for testing students' learning in the *PET* program. Two noted that assessments outside of the *PET* program do not work well for measuring the knowledge gained by these students because of the difference between "*PET* language" and traditional physics language. Another stated that the *PET* testing is constructed to show "how well it [the *PET* program] took" rather than how well the science ideas took; he thinks the science is well learned, but he is not sure.

- **Final Comments and Suggestions.** When asked what else they would like to see in the *PET* program and what else they would like to say about it, once again, the overwhelming majority of interviewees responded with very positive comments. They report that they find it to be an excellent program, "terrific," they enjoy teaching it; they find it well put together and easy to teach. One states, *"The curriculum is all self-contained and the online teacher guide is excellent, so it is easy to teach from that standpoint, and it is a lot of fun to teach because every single day you can see students learning, you get to see all those ah-ha moments. It's just really rewarding in a way that you just don't get with that big boring lecture class."* Several interviewees declared they believe the program is fine just as it is, they would not suggest changing anything.

One respondent describes the class this way: *"It's a fun group of students to work with and this program sets up a reasonable environment as well. The process of small groups works and we trade groups around after each cycle. We have a coffee pot going and we bring some snack in everyday to class. It all sort of works together in a non-threatening sense for these students."*

One interviewee commented that while she finds the program to be work-intensive for the instructor, "I really like it." Again interviewees reiterate that with this program they can see the students learning and see their attitudes about science change. Participants also named several specific aspects of the program they appreciated, including that the program focuses on ideas and teaches conceptually, that it is inquiry-based, that it is "full of interesting ideas about how to teach physics," that it "spirals" back to important ideas, and that it includes supporting materials like "tips" about how students may respond. One respondent said, "Don't let the publisher stop publishing it." Another expressed gratitude to the National Science Foundation for funding the development of the program.

Among the suggestions participants provided for improvement to the *PET* program, there were no ideas or concerns consistently identified across several individuals. A few comments addressed the *PET* program as a whole. One participant states that in the beginning it was hard to adjust to the *PET* methods as an instructor, stating, *"If you are going to play by the game plan, you can't give out answers. I often tell people I stopped telling students 'you're wrong' a long time ago. That wasn't a problem. But now with this class I have to start telling them 'you're right.' That's hard."* Another would like more training. Another respondent states that it is difficult not to lecture, and if she designed the class she would have made it "more between lecture and inquiry," however the *PET* program is "much better than what we had before." One participant remarked that it would be helpful to share experiences and "what works" with others.

Most of the suggestions provided by the respondents addressed specific elements of the curriculum or materials. Among these, one respondent noted the program "shies away from math too much"; another said it lacks chemistry subject matter. Other respondents mentioned a need for additional lessons on static electricity, color, and series and parallel circuits. One individual suggested optional activities, such as on nuclear chemistry and radio chemistry. Other comments include a concern that the section on acceleration is not clear enough, the refraction homework assignment is very difficult for students, the "ear and eye brain energy" section is too "dumbed down," there needs to be more homework, the homework needs to be upgraded, and it would be helpful to make the homework less labor-intensive to grade. Two respondents would like to see more ESIs, simulations, and videos. One would like help with strategies for managing group work, especially pacing. One respondent notes the website needs updates and completion; another suggests putting the website information onto DVDs or CDs to avoid technological problems; and another states "the more technology integrated in the program the better." Finally, noting the difficulty with assessing the effectiveness of this program, one respondent suggests setting up different testing methods to show the class is successful.

APPENDIX A:
Sample Detailed Report of Results of Student Pre/Post Testing

Reports similar to this were prepared for each of the field test sites and are available from the *PET* project director. This final report provides a summary of findings across all sites in an earlier Evaluation Findings section.

***Physics and Everyday Thinking* (*PET*)**

Results of Pre/Post Tests
from Undergraduate Physics Classes
Using CPU-*PET* Instructional Materials
Winter/Spring 2005

Prepared by Science and Mathematics Program Improvement (SAMPI)—Western Michigan University

BACKGROUND. CPU-*PET* is a National Science Foundation-funded project to develop instructional materials, including web-based support materials, and associated professional development materials, to improve college-level physics education. The instructional materials have been designed for use in college-level physical science courses for prospective (pre-service) elementary teachers or workshops for practicing (in-service) elementary teachers.

In Summer 2004, developers of the materials conducted a five-day workshop on the use of the draft *PET* materials for a cadre of college physics instructors from 4-year and 2-year colleges across the United States. These instructors created new courses based on *PET* materials or integrated *PET* materials into existing physics courses and implemented them during the 2004-05 school year.

As one way to assess the impact of the program on the teacher participants, developers devised a seven-item content-based test. Each test item included a scenario related to a physics topic covered in the course, followed by a question requiring students to choose from a set of answers or complete an illustration. In each case, students were also asked to explain their answers. A scoring rubric was created by the test developers that assessed both choice of answers and written explanations.

PET external evaluators scored the tests and completed the analysis of results for the University of Wisconsin—Whitewater—Class #1 *PET*-supported classes. What follows are the findings from that analysis.

SAMPLE. The test was administered in the workshop in Winter/Spring 2005. A total of 23 undergraduates completed the pre-course test and 20 completed the post-course test. A total of 20 undergraduate participants completed both the pre- and post-course tests. The analysis below is based only on those who completed both the pre- and post-tests.

Six were freshmen, 8 sophomores, 6 juniors, and 3 seniors. All had taken at least one science course in high school (1 course = 1, 2 = 1, 3 = 3, 4 = 11, 5 = 5, 6 = 3, and 7 = 1.) For 9 students, this was their first college-level science class; 7 had one class before this one, 3 had two classes, 1 had 3 classes, 1 had 4 classes, and one had 6 science classes. Asked to rate their interest in science on a 3-point scale, 7 indicated a “high” interest, 10 indicated “some” interest, and 5 indicated “little” interest.

PRE- AND POST-TEST SCORES. The charts below show the number and percent of teacher participants scoring at each point level for the total test score and for individual item scores. These data are based on scores from the 20 students across the class who completed both the pre- and post-course tests.

Total Test Score. The highest possible score was 25.

Table 1: Total Test Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	0	0%	0	0%
1	0	0 %	0	0%
2	2	10.0%	0	0%
3	2	10.0%	0	0%
4	5	25.0%	0	0%
5	6	30.0%	0	0%
6	2	10.0%	1	5.0%
7	3	15.0%	0	0%
8	0	0%	1	5.0%
9	0	0%	2	10.0%
10	0	0%	1	5.0%
11	0	0%	1	5.0%
12	0	0%	1	5.0%
13	0	0%	3	15.0%
14	0	0%	2	10.0%
15	0	0%	3	15.0%
16	0	0%	2	10.0%
17	0	0%	0	0
18	0	0%	1	5.0%
19	0	0%	1	5.0%
20	0	0%	0	0%
21	0	0%	1	5.0%
22	0	0%	0	0%
23	0	0%	0	0%
24	0	0%	0	0%
25	0	0%	0	0%

Test Item #1. This item asks students to identify the forces involved in a soccer player kicking a ball straight up into the air and then catching it when it falls back down. Students are asked to explain their answer. The highest possible score is 3.

Table 2: Test Item #1 Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	5	25%	5	25%
1	14	70%	2	10%
2	1	5%	8	40%
3	0	0	5	25%

Test Item #2. In this item students are asked to pick from a set of choices that best describes the motion of a puck being pushed by a hockey player with a "constant strength push." Students are asked to explain the reasoning behind their choice. The highest possible score is 3.

Table 3: Test Item #2

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	16	80%	13	65%
1	3	15%	0	0
2	0	0	0	0
3	1	5%	7	35%

Test Item #3. For this item, students are told that a large block is on rollers so that it can move across a surface as if there is no friction affecting it. After it has started moving to the right, two men want it to continue in the same direction at a constant speed. Drawings of four possible situations are provided. Students are asked to indicate which situations would result in the block moving to the right in a constant speed after it has already started moving. They are also asked to explain their reasoning. The highest possible score is 3.

Table 4: Test Item #3 Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	17	85%	8	40%
1	1	5%	1	5%
2	1	5%	9	45%
3	1	5%	2	10%

Test Item #4. Students are provided with a drawing of a young boy sitting on a bed eyeing an apple with a lamp on his night table, the only light source in the room, directly behind him. They are told the ceiling and walls are painted a non-shiny white color. Students are asked to draw how the boy can see the apple, including arrows, and labeling what they draw. Then they are asked to explain how the boy is able to see the apple. The highest possible score is 5.

Table 5: Test Item #4 Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	1	5%	0	0
1	3	15%	1	5%
2	16	80%	12	60%
3	0	0	2	10%
4	0	0	1	5%
5	0	0	4	20%

Test Item #5. Students are told about a boy with a wind-up car with a coiled spring inside. The boy holds the car on the floor, winds the spring, and then lets go of the car. The car speeds up quickly, then moves along at a nearly constant speed for a while, then slows down to a stop. Students are given four possible statements that could be made about what was happening to the car. Then they are asked to identify the statement that best describes what was happening, in terms of energy, during four different points in the car's journey. For each point in the car's journey, they are asked to give their reasons for their choice. The highest possible score is 5.

Table 6: Test Item #5 Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	15	75%	1	5%
1	3	15%	1	5%
2	2	10%	4	20%
3	0	0	4	20%
4	0	0	9	45%
5	0	0	1	5%

Test Item #6. Students were shown an electrical circuit with a single battery connected to two identical light bulbs. Two students, “Daryl” and “Luisa,” offered their predictions about how the brightness of the two light bulbs would compare when the circuit was tested. Students were then asked whether they agreed with Daryl, Luisa, both of them, or neither of them. They were asked to explain their answer. The highest possible score is 3.

Table 7: Test Item #6 Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	11	55%	3	15%
1	5	25%	6	30%
2	3	15%	4	20%
3	1	5%	7	35%

Test Item #7. Students were shown the sane drawing of two different circuits with bulbs and batteries as in question #6. Both Daryl and Luisa predicted how the brightness of a particular bulb in the one circuit would compare with the brightness of a different bulb in the second circuit. Then students were asked whether they agreed with Daryl, Luisa, both of them, or neither of them, and to explain their answer. The highest possible score is 3.

Table 8: Test Item #7 Scores

	Pre-Test		Post-Test	
Score	No. Students	% Students	No. Students	% Students
0	14	70%	7	35%
1	3	15%	0	0%
2	3	15%	3	15%
3	0	0%	10	50%

RESULTS OF A PAIRED t-TEST. In order to determine the statistical significance of changes from pre- to post-test scores, a paired t-test was done for each item as well as for the total score. The chart below shows the results. Except for item 2, the change in scores from pre- to post-test was significant at alpha <= 0.01 for each item. This suggests that overall student responses to test items were significantly higher (based on the scoring rubric criteria) from pre- to post-tests.

Table 9

	Pre-Test Average Score	Post-Test Average Score	Gain Score
Total Score (highest possible score = 25)	4.65	13.35	8.70*
Item 1 (highest possible score = 3)	0.80	1.65	0.85*
Item 2 (highest possible score = 3)	0.30	1.05	0.75
Item 3 (highest possible score = 3)	0.30	1.25	0.95*
Item 4 (highest possible score = 5)	1.75	2.75	1.00*
Item 5 (highest possible score = 5)	0.35	3.10	2.75*
Item 6 (highest possible score = 3)	0.70	1.75	1.05*
Item 7 (highest possible score = 3)	0.45	1.80	1.35*

* Statistically significant change from pre- to post-test (alpha <=0.01)

ANALYSIS OF ACCEPTABLE SCORE LEVELS BY ITEM. The tables below present counts of participants' test scores for each item. The row totals represent the number of participants scoring at each initial test value (pre-test), while the columns distribute the counts according to the post-test score over the pre-test. The rightmost columns show totals of the counts and percents, first totaling for all scores and then for those of the desirable or acceptable outcomes. Acceptable = post-test score of two or three for items 1, 2, 3, 6, and 7 and score of three, four or five for items 4 and 5. In each table, a diagonal is indicated by shaded cells from the upper left corner to the lower right: The shaded cells show the counts of participants whose pre- and post-tests received the same score—they did no better or worse on the post-test than they did on the pre-test. For cells occurring above and to the right of the shaded cell, the participants' scores increased from pre to post, and for cells below and to the left, the scores decreased. The vertical line in the middle of the table divides cells that fall within the desirable/acceptable outcomes range (to the right of the line) from the other outcomes (to the left of the line).

Table 10: Post-test scores compared to pre-test : Item 1, UW class 3

		Post-test Score					
Pre-test Score		0	1	2	3	Total	Acceptable/ Desirable Outcome*
0	Count	2	0	3	0	5	3
	Percent	40%	.0%	60.0%	.0%	100%	60%
1	Count	3	2	5	4	14	9
	Percent	21.4%	14.3%	35.7%	28.6%	100%	64%
2	Count	0	0	0	1	1	1
	Percent	.0%	.0%	.0%	100%	100%	100%
3	Count	0	0	0	0	0	
	Percent						
Total	Count	5	2	8	5	20	13
	Percent	25%	10%	40%	25%	100%	65%

*An acceptable/desirable outcome is a score of 2 or 3.

Table 11: Post-test scores compared to pre-test : Item 2, UW class 3

		Post-test Score					
Pre-test Score		0	1	2	3	Total	Acceptable/ Desirable Outcome*
0	Count	9	0	0	7	16	7
	Percent	56.3%	.0%	.0%	43.8%	100.0%	44%
1	Count	3	0	0	0	3	0
	Percent	100.%	.0%	.0%	.0%	100.%	0%
2	Count	0	0	0	0	0	
	Percent						
3	Count	1	0	0	0	1	0
	Percent	100.0%	.0%	.0%	100.0%	100.0%	0%
Total	Count	13	0	0	7	20	7
	Percent	65.0%	.0%	.0%	35.0%	100.0%	35%

*An acceptable/desirable outcome is a score of 2 or 3.

Table 12: Post-test scores compared to pre-test : Item 3, UW class 3

Pre-test Score		Post-test Score				Total	Acceptable/ Desirable Outcome*
		0	1	2	3		
0	Count	8	1	7	1	17	8
	Percent	47.1%	5.9%	41.2%	5.9%	100.0%	47%
1	Count	0	0	1	0	1	1
	Percent	.0%	.0%	100.0%	.0%	100.0%	100%
2	Count	0	0	1	0	1	1
	Percent	.0%	.0%	100.0%	.0%	100.0%	100%
3	Count	0	0	0	1	1	1
	Percent	.0%	.0%	.0%	100.0%	100.0%	100%
Total	Count	8	1	9	2	20	11
	Percent	40.0%	5.0%	45.0%	10.0%	100.0%	55%

*An acceptable/desirable outcome is a score of 2 or 3.

Table 13: Post-test scores compared to pre-test : Item 4, UW class 3

Pre-test Score		Post-test Score						Total	Acceptable/ Desirable Outcome**
		0	1	2	3	4	5		
0	Count	0	0	0	0	0	1	1	1
	Percent	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%	100%
1	Count	0	1	2	0	0	0	19 100.0%	6 32%
	Percent	.0%	33.3%	66.7%	.0%	.0%	.0%		
2	Count	0	0	10	2	1	3		
	Percent	.0%	.0%	62.5%	12.5%	6.3%	18.8%		
3	Count	0	0	0	0	0	0	0	
	Percent								
4	Count	0	0	0	0	0	0	0	
	Percent								
5	Count	0	0	0	0	0	0	0	
	Percent								
Total	Count	0	1	12	2	1	4	20	7
	Percent	.0%	5.0%	60.0%	10.0%	5.0%	20.0%	100.0%	35%

**An acceptable/desirable outcome is a score of 3 to 5.

Table 14: Post-test scores compared to pre-test : Item 5, UW class 3

Pre-test Score		Post-test Score						Total	Acceptable/ Desirable Outcome**
		0	1	2	3	4	5		
0	Count	0	1	2	4	8	0	15	12
	Percent	.0%	6.7%	13.3%	26.7%	53.3%	.0%	100.0%	80%
1	Count	1	0	1	0	0	1	5	2
	Percent	33.3%	.0%	33.3%	.0%	.0%	33.3%	100.0%	40%
2	Count	0	0	1	0	1	0		
	Percent	.0%	.0%	50.0%	.0%	50.0%	.0%		
3	Count	0	0	0	0	0	0	0	
	Percent								
4	Count	0	0	0	0	0	0	0	
	Percent								
5	Count	0	0	0	0	0	0	0	
	Percent								
Total	Count	1	1	4	4	9	1	20	14
	Percent	5.0%	5.0%	20.0%	20.0%	45.0%	5.0%	100.0%	70%

**An acceptable/desirable outcome is a score of 3 to 5.

Table 15: Post-test scores compared to pre-test : Item 6, UW class 3

Pre-test Score		Post-test Score				Total	Acceptable/ Desirable Outcome*
		0	1	2	3		
0	Count	3	4	2	2	11	4
	Percent	27.3%	36.4%	18.2%	18.2%	100.0%	36%
1	Count	0	2	1	2	5	3
	Percent	.0%	40.0%	20.0%	40.0%	100.0%	60%
2	Count	0	0	1	2	3	3
	Percent	.0%	.0%	33.3%	66.7%	100.0%	100%
3	Count	0	0	0	1	1	1
	Percent	.0%	.0%	.0%	100.0%	100.0%	100%
Total	Count	3	6	4	7	20	11
	Percent	15.0%	30.0%	20.0%	35.0%	100.0%	55%

*An acceptable/desirable outcome is a score of 2 or 3.

Table 16: Post-test scores compared to pre-test : Item 7, UW class 3

		Post-test Score					Acceptable/ Desirable Outcome*
Pre-test Score		0	1	2	3	Total	
0	Count	4	0	2	8	14	10
	Percent	28.6%	.0%	14.3%	57.1%	100.0%	71%
1	Count	2	0	1	0	3	1
	Percent	66.7%	.0%	33.3%	.0%	100.0%	33%
2	Count	1	0	0	2	3	2
	Percent	33.3%	.0%	.0%	66.7%	100.0%	67%
3	Count	0	0	0	0	0	
	Percent						
Total	Count	7	0	3	10	20	13
	Percent	35.0%	.0%	15.0%	50.0%	100.0%	65%

*An acceptable/desirable outcome is a score of 2 or 3.

Table 17

CPU-*PET* Fall 2004
Content Test - UW
Counts of Desirable/Acceptable Post-test Outcomes*
Distributed over Pre-test Scores

Pre-test			Post-test Total Score >= 13	
Total Pre-test Score	No. of tests	Percent	No. of tests	Percent
2	2	10%	0	0%
3	2	10%	1	50%
4	5	25%	4	80%
5	6	30%	5	83%
6	2	10%	1	50%
7	3	15%	2	67%
Total Tests	20	100%	13	65%

*An acceptable/desirable outcome is a total post-test score of 13 to 25.

CHANGES IN SCORES FROM PRE- TO POST- TESTS. The tables below show the frequencies of the various changes in test scores from pre to post. N = 20

Table 18: ITEM #1 (up to 3 points possible)

Change from ___ to ___	Percent
0 to 0	10%
0 to 2	15%
1 to 0	15%
1 to 1	10%
1 to 2	25%
1 to 3	20%
2 to 3	5%

Table 19: ITEM #2 (up to 3 points possible)

Change from ___ to ___	Percent
0 to 0	45%
0 to 3	35%
1 to 0	15%
3 to 0	5%

Table 20: ITEM #3 (up to 3 points possible)

Change from ___ to ___	Percent
0 to 1	5%
0 to 2	35%
0 to 3	5%
0 to 0	40%
1 to 2	5%
2 to 2	5%
3 to 3	5%

Table 21: ITEM #4 (up to 5 points possible)

Change from ___ to ___	Percent
0 to 5	5%
1 to 1	5%
1 to 2	10%
2 to 2	50%
2 to 3	10%
2 to 4	5%
2 to 5	15%

Table 22: ITEM #5 (up to 5 points possible)

Change from ___ to ___	Percent
0 to 1	5%
0 to 2	10%
0 to 3	20%
0 to 4	40%
1 to 0	5%
1 to 2	5%
1 to 5	5%
2 to 2	5%
2 to 4	5%

Table 23: ITEM #6 (up to 3 points possible)

Change from ___ to ___	Percent
0 to 0	15%
0 to 1	20%
0 to 2	10%
0 to 3	10%
1 to 1	10%
1 to 2	5%
1 to 3	10%
2 to 2	5%
2 to 3	10%
3 to 3	5%

Table 24: ITEM #7 (up to 3 points possible)

Change from ___ to ___	Percent
0 to 0	20%
0 to 2	10%
0 to 3	40%
1 to 0	10%
1 to 2	5%
2 to 0	5%
2 to 3	10%

Appendix B
Physics for Elementary Teachers (*PET*)
Record of Administration of Pre/Post Content Tests in College Classes and Summer In-Service Teacher Workshops

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Fall 03	- Black Hills State University - Furman University - Idaho State University - San Diego State University - Tennessee Tech—Group 1, 2, 3 (Combined report) - Western Washington University
Winter-Spring 04	- Buffalo State University - Idaho State University - San Diego State University—Group 1 - San Diego State University—Group 2 - Tennessee Technological University—Group 1 - Tennessee Technological University—Group 2 - Tennessee Technological University—Group 3 - Western Washington State University—Group 1 - Western State University—Group 2
Summer 04	- Black Hills State University (in-service teacher workshop) - Buffalo State University (in-service teacher workshop) - Furman University (in-service teacher workshop) - Idaho State University (in-service teacher workshop) - Western Washington—Full Test (in-service teacher workshop) - Western Washington—Partial Test (in-service teacher workshop)
Fall 04	- Louisiana State University - Purdue University - Tennessee Technological University—1 - Tennessee Technological University—2 - Tennessee Technological University—3 - University of Nebraska - University of Michigan—Dearborn - University of Minnesota—Group 1 - University of Minnesota—Group 2 - University of Wisconsin—Whitewater—Group 1 - University of Wisconsin—Whitewater—Group 2
Winter-Spring 05	- Ball State University—Lecture - Ball State University—Lab - El Camino College - Jamestown Community College - Louisiana State University—Group 1 - Louisiana State University—Group 2 - NE Arkansas Community College - University of Arkansas - University of Michigan—Dearborn—Group 1 - University of Michigan—Dearborn—Group 2 - University of Michigan—Dearborn—Summer - University of Minnesota—Group 1 - University of Minnesota—Group 2

Appendix C
Formal Evaluation Reports Produced

Over the course of the project, evaluators prepared a variety of reports based on specific data collection efforts that were shared with the project management team. Below is a list of the major reports. They are available from the *PET* project director.

Pilot Test Faculty

- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—Black Hills State University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—Buffalo State College
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—Furman University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—Idaho State University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—San Diego State University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—Tennessee Technical University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Fall 2003—Western Washington University
- Compilation of Pre/Post Tests Among Pilot Test Classes—Fall 2003—All Classes

- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—Black Hills State University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—Buffalo State College
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—Furman University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—Idaho State University
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—San Diego State University (2 classes)
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—Tennessee Technical University (3 classes)
- Results of Pre/Post Test from Classes Using *PET* Instructional Materials—Winter/Spring 2004—Western Washington University (2 classes)

- End-of-Class Student Survey—Compilation of Responses—Fall 2003—Black Hills State University
- End-of-Class Student Survey—Compilation of Responses—Fall 2003—Buffalo State College
- End-of-Class Student Survey—Compilation of Responses—Fall 2003—Furman University
- End-of-Class Student Survey—Compilation of Responses—Fall 2003—Idaho State University
- End-of-Class Student Survey—Compilation of Responses—Fall 2003—San Diego State University
- End-of-Class Student Survey—Compilation of Responses—Fall 2003—Tennessee Technical University
- End-of-Class Student Survey—Compilation of Responses—Fall 2003—Western Washington University

- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—Black Hills State University
- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—Buffalo State College
- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—Furman University
- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—Idaho State University
- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—San Diego State University

- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—Tennessee Technical University
- End-of-Class Student Survey—Compilation of Responses—Winter/Spring 2004—Western Washington University

Field Test Faculty

- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—University of Nebraska
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—Purdue University
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—S.E. Louisiana State University (2 classes)
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—Tennessee Technical University (3 classes)
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—University of Michigan—Dearborn
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—University of Minnesota (2 classes)
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2004—University of Wisconsin—Whitewater (2 classes)

- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—El Camino College
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—Jamestown Community College
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—Ball State University—Lab
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—Ball State University—Lecture
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—Purdue University
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—University of Arkansas
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—University of Minnesota (2 classes)
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—University of Michigan—Dearborn (3 classes)
- Results of Pre/Post Tests from Undergraduate Physics Classes Using *PET* Instructional Materials—Fall 2005—University of Wisconsin—Whitewater (2 classes)

In-Service Teachers

- Compilation of Responses to End-of-Session Evaluation Questionnaire—Summer 2004—Black Hills State University
- Compilation of Responses to End-of-Session Evaluation Questionnaire—Summer 2004—Buffalo State College
- Compilation of Responses to End-of-Session Evaluation Questionnaire—Summer 2004—Furman University
- Compilation of Responses to End-of-Session Evaluation Questionnaire—Summer 2004—Idaho State University
- Compilation of Responses to End-of-Session Evaluation Questionnaire—Summer 2004—Western Washington University (2 workshops)

- Results of Pre/Post Tests from In-Service Teacher Workshops Using *PET* Instructional Materials—Summer 2004—Black Hills State University
- Results of Pre/Post Tests from In-Service Teacher Workshops Using *PET* Instructional Materials—Summer 2004—Buffalo State University

- Results of Pre/Post Tests from In-Service Teacher Workshops Using *PET* Instructional Materials—Summer 2004—Furman University
- Results of Pre/Post Tests from In-Service Teacher Workshops Using *PET* Instructional Materials—Summer 2004—Idaho State University
- Results of Pre/Post Tests from In-Service Teacher Workshops Using *PET* Instructional Materials—Summer 2004—Western Washington University (2 workshops)

- In-Service Teacher Summer Workshop and School-Year Follow-up (2004-05) Participant Surveys—Analysis of Responses—June 2005—All sites

- *PET* Jr. Field Test Compilation of Responses from Feedback Form—Current Electricity
- *PET* Jr. Field Test Compilation of Responses from Feedback Form—Forces and Motion
- *PET* Jr. Field Test Compilation of Responses from Feedback Form—Light
- *PET* Jr. Field Test Compilation of Responses from Feedback Form—Magnetism