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Effect of a Concentrated In-service Elementary Teacher Force and Motion Workshop

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EFFECT OF A CONCENTRATED IN-SERVICE ELEMENTARY TEACHER FORCE AND MOTION WORKSHOP

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An Abstract of the Thesis Presented

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The National Science Education Standards and Maine Learning Results outline a comprehensive program for facilitating children's learning of basic concepts in force and motion. The program has goals for children as early as Kindergarten, but assumes the teachers in our primary schools are prepared to handle these concepts. Unfortunately our elementary school teacher's training programs do not require in-depth instruction in the sciences, and many of our elementary school teachers have never received instruction in basic physics. Lacking mastery of the content, many in-service teachers doubt their ability to present science material in their classrooms, and sometimes avoid the material all together. While standard summer coursework is available that might improve teacher understanding of the concepts, it is difficult for many teachers to commit to a summer long program. Short courses and workshops are offered as alternatives in a number of venues that try to address these deficiencies. This research project investigates whether a concentrated workshop format can have a lasting impact on in-service teacher conceptual understanding and self-efficacy as they relate to force and motion. A concentrated one-week workshop featuring inquiry-based learning and including epistemological topics was developed and administered during the summer of 2005. The Force and Motion Conceptual Evaluation (FMCE) was used to measure gain in conceptual understanding, and the Maryland Physics Expectations Survey (MPEX) and Science Teaching Efficacy Belief Instrument (STEBI) were used to evaluate teacher attitudes, beliefs, and expectations relating to their own physics understanding and its role in their classrooms. While improvement was evident in both the FMCE and MPEX results, it is not clear that the amount of improvement produced is sufficient to fully prepare in-service teachers to facilitate learning in this area.

DEDICATIONS

This document is dedicated to:

- My wife, Lisa, who put up with hours of work, and provided help, support and understanding when I needed it most, and also another set of eyes to help catch all of those silly errors.
- My son, Josh, who was often my guinea pig for new physics teaching ideas.
- My daughter Krystal, who provided support, hugs, and told me when to take time off.
- Mr. Donald Ridgeway, friend, advisor, and mentor who made my intern teaching assignment a fun and rewarding experience.

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CHAPTER 1 - INTRODUCTION

Traditionally elementary school teachers have been trained as generalists. They are required to have a broad background in a large number of subjects. However, this breadth of training has left little room for depth in any of the sciences. As part of this thesis we will review the issue of elementary teacher training and professional development in light of state and national science teaching standards, and in the framework of concepts in force and motion. We will also review the effectiveness of a concentrated five-day workshop in improving content knowledge and teacher self-efficacy.

In the past, professors at universities across the country (and around the world!) have sometimes viewed students as blank slates, ready to begin learning the basic principles about the world around them. They have often been surprised by the interesting, but not quite correct, ways many students find to view the most basic concepts. It seems that students actually arrive with a "slate" that has already been partially inscribed, and that some of the most difficult parts of teaching are involved in erasing or reorganizing the material already in place. In the early 1980's researchers involved in physics education began to seriously investigate the apparent disconnect. People like Trowbridge and McDermott[1] at the University of Washington, Clement[2] at the University of Massachusetts, and Minstrell[3] at Mercer Island High School began to look at the situation, finding and documenting issues with student learning. The Duit Bibliography[4] lists hundreds of other papers related to this topic. Researchers began using the terms *misconception* and *alternative conception* as ways of describing the disconnect between how students think the world works and how the most recent theories in physics view the same situations. Some began to talk about the tools and knowledge that students use to assemble their understanding and how those might play into the understanding that students develop.

The early researchers in childhood learning and development, including Piaget[5] and Vygotsky,[6] found that children were capable of learning at very early ages, and that they develop much of their understanding of the world through observation and interaction with other people as they are growing up. Other researchers found that in the absence of instruction the understanding developed could take some peculiar twists. Many concluded that instruction in our schools, even in the elementary grades, might help to guide the developing understanding of students. As the body of research and literature on student learning grew it became more and more obvious that there might be ways to improve understanding, and that some of that work could take place at the earliest levels of our school systems.

In the early 1980's educators and administrators across the country were also noticing what they perceived as a decline in the education level of students at all levels of our school system. In 1981 the U.S. Secretary of Education appointed the National Commission on Excellence in Education to investigate the condition of America's schools, and to report on problems and potential solutions to a perceived erosion in the education of American children. The Commission responded in 1983 with *A Nation At Risk,*[7] which identified, among other things, a need to reform our schools and their curricula. In 1985 the American Association for the Advancement of Science (AAAS) initiated Project 2061 (the year of the next return of Halley's Comet) as a means to begin that reform. Project 2061 attempted to "establish a conceptual base for reform by spelling out the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience from kindergarten through high school." In *Science for All Americans*[8] the AAAS reported on its findings, laid the groundwork for curriculum reform, and advocated for improvement in the education of teachers, increased use of technology, and improved testing and assessment tools. Many organizations responded to the challenge presented by *A Nation At Risk* and *Science for All Americans.* In 1986 the National Science Foundation began issuing grants for research in this area under the Triad Projects. The National Council of Teachers of Mathematics' *Standards for Content and Evaluation,*[9] The Biological Sciences Curriculum Study's *Developing Biological Literacy,*[10] and the AAAS *Benchmarks for Science Literacy*[11] are examples of the effort put forth. In the early 1990's the National Science Teachers Association (NSTA) began to prepare the document that would become the *National Science Education Standards (NSES),*[12] a comprehensive treatise covering standards for: science teaching; teacher professional development; assessments; content that should be required in K-12 programs; education programs; and educations systems.

Many states, including Maine, have used these and their own experiences to develop state standards.

In spite of the work on student understanding and educational standards students still arrive at universities unable to meet the demands of the physics classroom. What happened to sidetrack the predicted improvement? One possible explanation is that the teachers involved in helping to shape the understanding of these children were never adequately prepared for the challenge. State certification, university graduation, and professional development requirements for elementary teachers all contribute to this problem. We will review these issues related to elementary teacher preparation and also the effectiveness of a concentrated five-day workshop in improving content knowledge and teacher self-efficacy.

Organization

This thesis is organized in eight chapters. Following the Introduction, the second chapter briefly discusses the development of physics understanding in children and the different models of learning used to describe their understanding as it develops. It also looks at the programs laid out by the National Science Education Standards (NSES) and Maine Learning Results (MLR) for addressing those deficiencies starting in the elementary grades, and briefly discusses how children are capable of good physical reasoning, even at early ages. The third chapter looks at the state requirements for teaching in elementary schools and the university program requirements for teaching degrees and compares them to the documented needs in the MLR and other standards. It shows that there is a disconnect between what we expect our teachers to do and the preparation they receive to do it. The fourth chapter discusses some development options available for in-service teachers, presents a case for using a concentrated one-week summer workshop, and outlines some of the content a successful workshop might contain. Chapter five discusses our summer workshop curriculum and its development, chapter six covers the results of the summer physics workshop. Chapter seven includes discussion of the results, and chapter eight summarizes our conclusions from the workshops.

CHAPTER 2 – STUDENT DEVELOPMENT IN PHYSICS

It is well documented that students come to university level physics with a variety of conceptual tools. Trowbridge and McDermott[13] described some of these tools as "*preconceptions*" and "*protoconcepts*," and noted that they included, "… *a repertoire of procedures, vocabulary, associations, and analogies* …." Hammer and Elby[14] modeled another element of reasoning important to learning in terms of epistemological resources. They noted that students bring "*clusters of resources*" and a "*resource framework*" to their classes. Redish[15] synthesized these and other ideas into a resource framework that can be used to model the learning process. Others have described conceptual tools in other ways; diSessa[16] used "*phenomenological primitives" ("p-prims")*to discuss the most basic knowledge elements, Southerland[17] used the term "*conceptual framework"* to describe how knowledge bits, including p-prims, are organized and used.

Regardless of the terminology, the research indicates that students begin their university classes with a set of tools for explaining the world they see. However, in many cases those ideas are incomplete, erroneous, or misapplied. A robust research result is that many students do not see the world in a way that matches current physical theory. To gauge the level of Newtonian thinking by students Hestenes, Wells, and Swackhamer[18] developed the Force Concept Inventory (FCI), a 30-item multiple choice survey designed using research on student thinking about physics. These researchers found that entry level students typically scored only 30-40% on the FCI as a pretest. At the University of Washington Trowbridge and McDermott[13] found that 15% of the technically oriented, and 30-40% of non-technical students incorrectly interpreted a basic velocity comparison in precourse interviews. They also found that over 60% of their students incorrectly interpreted a basic acceleration comparison.[19] Later Thornton and Sokoloff[20] developed the Force and Motion Conceptual Evaluation (FMCE), a 47-question multiple choice assessment of student understanding of basic force and motion concepts (similar to the FCI), and using it found that over 80% of the non-calculus physics students at the University of Oregon and Tufts University answered questions in a non-Newtonian fashion.

How do students arrive with this mixed bag of skills? Should they be learning some of this material earlier in our school systems? Should they complete their elementary and secondary schooling with a consistent set of resources for describing the world around them?

Development of Children's Resources

Some of the earliest research into in modern cognitive learning theory was conducted by Piaget[5] and Vygotsky,[6] whose work with children attempted to determine what children can learn, and how early in life they can learn it. Byrnes[21] discussed some of the major theories of how children learn from Piaget, Vygotsky, and others, indicating that children begin the long climb to acquisition of knowledge and learning very early:

- He noted that Piaget's work showed students were capable of *concrete operational*[a] thought as early as five or six, and they continue to develop throughout their school years.

- He related how *Schema theory*[b] identified some of the likely thought structures that students develop, and how information may be integrated into those structures.

- He discussed how Vygotsky[c] stressed the need for social interaction in learning, and that communication is essential to higher order thought.

Byrnes[22] also summarized the work of many other researchers to conclude that children as young as five develop their own misconceptions and naïve physics theories.

Similarly, the p-prims described by diSessa,[23] Southerland,[17] and others describe very basic, but not always correct, resources that many students have developed prior to entering school. Summarizing the work of Hammer and Elby, Redish, and others, Tuminaro[24] described resources as units of thought or reasoning which describe human thinking and learning. His concept of resources further abstracts the ideas of diSessa to show how p-prims can be shown to be

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[a] Concrete operational students are beginning to understand abstract concepts, are developing an understanding of spatial relationships (e.g., a squashed clay ball has the same amount of clay as a ball that has been rolled into a sausage shape). They are also beginning to see the need for rules, rather than expecting everything to meet their youthful fantasies.
[b] Schema are knowledge structures used to organize our thoughts and memories. For instance, the schema *dogs* is used to organize all of our knowledge of the animals we know as *dogs*. When confronted with an unknown animal we can pull out the dog schema, and compare it to the animal to determine if it is, in fact, a *dog*.
[c] Vygotsky noted that children needed to have concepts modeled before they can truly learn them. He theorized that learning took place in four stages, modeling by a teacher, individual work by the student with help and feedback from the teacher, individual work by the student with less help from the instructor, and finally individual mastery of the subject.

reasoning primitives that are used in a specific context. He noted that these reasoning primitives, and resources in general, are neither right nor wrong in themselves. Their rightness or wrongness can only be determined when they are used in a particular context. Matching resources and reasoning primitives properly to give an accurate picture of how the world functions is one way to model learning. As a complement to these ideas, Hammer and Elby[14] noted some epistemological resources that are initially developed outside of our school systems:

- "*knowledge as propagated stuff*" (things that are learned or passed on from another source – parents, siblings, and friends are all potential sources, but not always good sources!*);*
- "*knowledge as free creation*" (things that are made up by children, that arise spontaneously from the child's mind)*;* and
- "*knowledge as fabricated stuff*" (understanding that is assembled, or figured out, from other knowledge)

With all of this resource development taking place early in life, and much of it through unguided investigation by young children, is it any wonder that some interesting, but not necessarily correct, ideas creep in?

Some of the most basic elements of our formal education, tools like language and communications, are developed or refined while students are in school. Lemke[25] noted that "*… language is not just vocabulary and grammar: Language is a system of resources for making meanings*." Lemke also noted

"*Students use their own language to put together a view of the subject* (science) *that can be very different* (from the teacher's)." To illustrate the language development envisioned by Lemke, and the theoretical framework of Redish, most students would probably start school with a basic understanding of ***fast*** as something like cars driving on the highway, or balls flying through the air. But that understanding is only valid in specific context and lacks generality to allow comparisons in other areas, so elementary curricula should extend the student intuitions to show how ***fast*** can apply to both turtles and cheetahs. The resource ***fast*** is correct when used to describe a turtle relative to a snail, but wrong when used to describe the same turtle relative to a cheetah. Students should also be led to understand that describing the context is essential to conveying the intended meaning of words like ***fast***.

We have summarized how children's thinking develops as they learn to explain the world around them. We can also discuss elements of *conceptual change* and the changes that can occur in student reasoning as their conceptual tools are refined into more formal structures. Demastes, Good, and Peebles[26] said this process "…lies at the heart of science teaching and learning." More fully, this process requires learners of any age to "… experience dissatisfaction with their original conception as well as judge a competing conception to be more intelligible, plausible, and fruitful …"[d] than any of the other conceptions available. diSessa and Sherin[27] noted that conceptual change can also take place by changing the relations that connect concepts. For instance, in changing from the

[d] Although quoted from Demastes et al. this idea originated with Posner, Strike, Hewson, and Gertzog[40]

concept “there is no <u>motion</u> without force” to the more expert concept “there is no <u>acceleration</u> without force” may not require changes in any of the basic concepts of motion, force, and acceleration, just a reorganization of that knowledge. diSessa and Sherin defined the term “*coordination classes*” to describe ways of organizing information gathered from the world around us. Coordination classes could be viewed as ways of connecting resources in meaningful, scientific ways, to produce a valid picture of how the world functions.[e] Organizational structure should also be part of the development supported by our schools. Our students should develop coordination classes for gathering and “reading out” resources describing the world around them.

Building on the work of Collins and Ferguson[28] and Redish,[15] Tuminaro[14] described a set of “epistemic games,” that can be used to help explain how students go about constructing new knowledge. He used the following definition from Redish to describe an epistemic game as *“… a coherent activity that uses particular kinds of knowledge and processes associated with that knowledge to create knowledge or solve a problem*.” An example is “Recursive Plug-and-Chug”, the game students play when they plug quantities into physics equations and crunch out numerical answers, without conceptual understanding of the physical implications of their calculations. Tuminaro indicated that some games

[e] Coordination classes include strategies for choosing what to notice and how to integrate the things we notice into our understanding of how the world works. As an example, children develop the ability to “find” objects during the early parts of their lives. As babies they are not much interested in objects that aren’t directly in view. As they get older they learn to track objects, but often do so ineffectively … sometimes by looking only in the last place they saw the object (in spite of information readily available that it isn’t there) or by looking around randomly. Only when they develop the ability to infer location from other information available can we say they have developed the coordination class “location of physical objects.”

were preferred by educators over others because they lead to a better understanding of the world, while other games are preferred by students because they seem “easier” or require lest effort. He implies that educators need to be mindful of the games their students are using, and keep them focused in the one the ones that are most productive. He also implies that students use epistemic games to access and utilize their resource, but in many ways these *games* are also resources in themselves. The right *game* can be used to activate the proper *resources* to result in a correct problem solution, or an improved and more viable view of the world.

Frames are another cognitive tool that is useful in the classroom environment. A *frame* is an individual’s interpretation of a situation based on their expectations of the situation. Although the concept of frames was pioneered and developed by others (Goffman[29], Fillmore[30], Tannen[31]), Redish[15] and Tuminaro[24] extended the work to look at how students use frames in a physics context. Redish noted that framing has many components including: social (*Who will I work with and how?*), physical (*What will I work with?*), skills (*What will I actually do?*), affect (*How will I feel about what I’m going to do?*) and epistemological (*How will I learn in this case?*). Understanding the frame that students are in plays a crucial role in selecting the teaching style used in a classroom.

The work of Piaget, Vygotsky, and others indicates our children develop the underpinnings for learning they will accomplish throughout their school years very early in life. Whether the ideas they develop are useful or detrimental depends to a great extent on the education they receive during these formative years. Combining ideas from cognitive theory and the findings that led to the development of the NSES, it seems our elementary school students should be:

- developing the language of science – this includes both the vocabulary and the context base to use in discussing science topics.
- beginning to create a set of tools with which they can understand the world – these should include the standard facts and concepts found in most text books, and also ways of relating those facts to each other and to new information as it is developed.
- constructing a coherent framework of science – one that stresses science is not simple unconnected facts, definitions, and equations, but a connected web of information with the web just as important as the information contained in it.

We should ensure development of a variety of cognitive tools for these students to use in creating knowledge. To ensure this development takes place in a coherent manner, some sort of framework should be in place to guide teachers and administrators in this task.

Standards for Teaching and a Roadmap for Student Development

In the late 1980's, in response to *A Nation At Risk*[7] and *Science for All Americans*[8] many educators, administrators, and scientists began the process of developing a clear picture of the science content needed in our schools. The

NSF sponsored TRIAD Projects produced a great deal of research into learning requirements, the schooling done in other countries, and the requirements of our society. Many papers were published, and many different curricula were developed. The thoughts behind this work slowly coalesced into standards, first with the *Content and Evaluation Standards*[9] developed by the National Council of Teachers of Mathematics, and later with the *National Science Education Standards (NSES)*[12] developed by the National Science Teachers Association (NSTA). These science standards provide a basic framework for teaching science in our classrooms, and provide a vision for how student development might take place. They include discussion of Inquiry as a basic component of the learning process, and of language as a unifying theme. The Standards are broken down by age group (grades K-4, 5-8, and 9-12) and content area. The Standards include these concepts in position and motion for grades K-4:

- The position of an object can be described by locating it relative to another object or the background.
- An object's motion can be described by tracing and measuring its position over time.
- The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.

The goals for grades 5-8 extend these concepts and include:

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

The framers of the Standards envisioned that they would be a living document that could be used as a guide for local and state representatives to develop the programs that make sense for their own areas. The Standards include the following comment:

> *"Continuing dialogues between those who set and implement standards at the national, state, and local levels will ensure that the Standards evolve to meet the needs of students, educators, and society at large."*

Many states, including Maine, have developed their own standards. The Maine Learning Results (MLR)[32] respond to the guidance of the Standards, and lay out a roadmap for development beginning with preschool students and continuing on through high school. The MLR were completed in 1997 at the direction of the Maine State Legislature as a way of promoting improved teaching and learning in Maine classrooms. The MLR include a section on *Motion*, with specific goals for students beginning in preschool and progressing on through high school. The complete *Motion* section of the MLR is included in Appendix A[f]. The examples below, from MLR, Section I, *Motion*, clearly indicate the drafters intended some very detailed learning for students in the later grades. In the middle grades (5-8) the MLR expects students to:

- Describe the motion of objects using knowledge of Newton's laws;
- Use mathematics to describe the motion of objects;

And in the secondary grades (9-12) the MLR expects students to:

- Use mathematics to describe the law of conservation of momentum;
- Use Newton's Laws to qualitatively and quantitatively describe the motion of objects.

These goals require teachers with a detailed and extensive knowledge of Newtonian physics. However, the goals for earlier grades are more modest, and consist more of developing a framework for later learning and a basis for the language used in later course work.

[f] As of 2006 the State of Maine was in the process of updating the MLR. The proposed MLR has a stronger focus on inquiry and technological design, but the Force and Motion goals, section D4 under the Physical Setting section are similar to the old MLR requirements. The proposed Force and Motion requirements are included in Appendix A for comparison.

The goals for the earliest grades (Preschool and Kindergarten through grade 2) include:

- Develop a variety of ways to describe the motion of an object.
- Demonstrate that the motion of an object can be changed.

Research shows that these MLR goals are consistent with the abilities and development demonstrated by younger children.

The MLR "roadmap" for elementary students stresses development of language and preparation of resources for more detailed learning in later years. The MLR approach, developing the framework and language early for use in later learning, is consistent with much of the modern research in education and learning. Lemke[25] noted that, "*Classroom language is not just a list of technical terms, or even just a recital of definitions. It is the use of those terms in relation to one another, across a wide variety of contexts.*" His point is that while science has a specific language that is similar to the common vernacular, how the language is used, and in what context, is just as important as the words themselves. Consistent with Vygotsky's views on social interaction and communication, learning the "language of science" is a social function as much as a technical one. According to Lemke, talking science *"… is based on participants sharing a common sense of the structure of the activity: of what's happening, what the options are for what comes next, and who is supposed to do what.*"

Developing the "language of science" requires more than just learning definitions. The MLR goals for preschool through 2nd grade focus on the development of the language and the context to describe motion. The goals for grades 3 and 4 extend the language development, and begin the process of learning concepts that explain the phenomena that students see in the world. While they are learning the concepts and language, they will also be developing the resources framework described by Hammer and Elby.[14] If that is done well, the framework is composed of epistemological resources that students can activate when solving problems or discussing "science." Redish[15] described this kind of theoretical framework as *"… a shared language and shared assumptions that can both guide and allow us to compare different approaches and ways of thinking."*

The map proposed by the MLR requires elementary teachers with a solid foundation in force and motion concepts and the ways in which students come to learn these concepts. They should possess – and have easy access to – the resources they hope to instill in their students. Unfortunately, that is not always the case.

CHAPTER 3 – ARE IN-SERVICE TEACHERS PREPARED TO TEACH FORCE AND MOTION?

Experts in the field of education have noted that development of our teachers is not what it could be. *A Nation At Risk*[7] *(1983)* identified some of the problems with our education system, concluding that, "*Half of the newly employed mathematics, science, and English teachers are not qualified to teach these subjects; fewer than one-third of U. S. high schools offer physics taught by qualified teachers.*" Later, *Science For All Americans*[8] *(1989)* noted that, *"Few elementary school teachers have even a rudimentary education in science and mathematics, and many junior and senior high school teachers of science and mathematics do not meet reasonable standards of preparation in those fields. Unfortunately, such deficiencies have long been tolerated by the institutions that prepare teachers, the public bodies that license them, the schools that hire them and give them their assignments, and even the teaching profession itself."*

Elementary school teachers in Maine, as in most other states, are required to have a broad background, with specific training in math, reading, writing, and theory of learning. They are not required to have specific training in the sciences, although most curricula include a requirement for at least some science courses.[*] Most teachers in our elementary schools choose their careers out of a desire to work with children, but many also have a desire to avoid "technical" subjects. This creates problems in two areas. First, teachers who dislike technical subjects, and even some who do like them, have trouble

[*] The University of Maine at Farmington requires 8 credits among biology, chemistry, geology, or physics. The University of Maine requires two courses in either biological or physical sciences, and one must be a lab course.

learning physics. Lawrenz[33] indicated that many in-service elementary school teachers may not have the needed foundation in technical subjects, and expressed a need to develop in-service teacher training programs to address the problem. Other researchers have found similar results (Trowbridge and McDermott,[13,19] Hestenes et al.,[18] Taylor and Lucas[34]). This is not surprising, given that these teachers have typically taken the very programs the researchers have found lacking, when they have taken college physics at all. In a recent survey of in-service teachers[35] in Maine we found that nearly half of the self-selected participants (8 out of 20) had never taken a physics class, and that another quarter had never progressed beyond high school physics. While this survey could hardly be called scientific, it does back up the findings of others that indicate that many in-service teachers have deficiencies in content understanding (Lawrenz, [16] Thurmond[36]). The second problem stems directly from the first. We have heard teachers and those training to be teachers make comments like, "I'm no good at science (or math, or some other topic)," expressing what Byrnes[37] would call negative ability beliefs related to their academic self-concept. In some cases the beliefs may be narrower and more akin to self-efficacy beliefs; "I can't understand electric circuits" would be an example. In an unpublished paper, Dykstra[38] comments that "standard" physics teaching techniques (those in use in almost all university programs until the late 1970's, and in most since then) are really systems for selecting and training a "physics elite." He further notes that, "*Most students leave this instruction having decided they cannot really understand physics and that they will have to rely on experts, really smart* *people, who know."* We should not be surprised that teachers produced by those techniques can have a poor self-image when it comes to understanding and teaching science to their students. It can be very difficult to get beyond those issues, and it appears that many teachers complete their training and enter the educational arena with those beliefs intact. Tilgner[39] found that half of elementary teachers rank science fourth or fifth out of five subjects. Recent survey results from Maine teachers[35] corroborate this idea; one teacher said, "*I find earth science near and dear to my heart, but other branches of science make me nervous with their language and rules …*" and another "… *science was one of my least favorite subjects*." A result of this attitude is the amount of time teachers spend teaching science in their classrooms. Tilgner found that one quarter do not teach science in their classrooms at all, while the remaining 75% spend less than two hours per week teaching science. While some of this is due to curriculum demands, and more recently increasing assessment demands from administrations and school boards, many of these teachers feel relieved by the outcome, rather than disturbed.

The problem in many cases isn't with the teacher's ability to learn, it is with their self-efficacy (what they believe they are capable of learning): they feel they aren't good at science and don't see the connection to what their students learn in elementary school. As a result they spend little effort in trying to learn sciences. Other teachers have developed interests in other areas, and so the limited time available in their training has taken them in other directions. We can use Posner's[40] "Conceptual Change Theory" as a vehicle to look at teacher preparation from another angle. Posner proposed that in order to make a change in conceptual framework four things must happen:

1) the student must be dissatisfied with the current situation
2) a new conception must be intelligible
3) a new conception must be plausible and
4) a new concept should be seen as fruitful.

It seems that this model can be used to describe teacher preparation as well. In order for teachers to branch out into new and uncomfortable territory they must first be dissatisfied with their current understanding. For some, this occurs during their initial training as they realize that they will need to cover the material with their future students. For others the dissatisfaction comes later, as they realize their conceptual framework is not adequately meeting the needs of the students they teach. In a recent survey[35] a third grade teacher in rural Maine said, "*I have never taken a physics class, and science was one of my least favorite subjects. I am enjoying it more now because I understand what I am teaching my students.*" Efforts like the MLR and the NSES Standards may provide a needed catalyst.

CHAPTER 4 – IN-SERVICE TEACHER PROFESSIONAL DEVELOPMENT OPTIONS

When dissatisfaction occurs, a program must be ready with material that can be understood by teachers who are not technically oriented, that is believable to them, and that ultimately provides them with something they see as useful in their classrooms. The most encompassing option would be a return to a university for full-time training or an additional degree. For some, evening, weekend, or summer classes might be an option. However, with the time consuming schedules that the teaching profession demands, these are often impractical or unpalatable solutions. Many teachers involved in our workshops commented that they would not have participated in a two-week session, let alone a semester-long course. A set of concentrated workshops targeted at specific areas like motion (or particular facets of biology or pre-algebra, etc.) might provide the bridge needed to move some teachers forward. And in fact, many professional development activities are scheduled in just this manner. These programs seem to be divided into two categories, those that concentrate on content, and those that concentrate on implementing a particular curriculum in the school.

Universities and colleges tend to focus on the first category. Their offerings tend to be more like normal courses, but concentrated into a shorter time frame. *Teaching Math the Way Children Think,*[g] *Science Workshop for K-6*

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[g] Teaching Math the Way Children Think, Brigham Young Summer Education Workshops, 4 day, 8 hour/day, 2 credit workshop; http://ce.byu.edu/cw/cwedwork/2005/week3.cfm#4

Teachers,[h] *Physics for Elementary Teachers,*[i] and the *NSF Summer Institute in Physics and Physical Science For Inservice Teachers*[j] are examples of the myriad of workshops and summer courses offered at many locations around the country. Trade organizations also offer professional development opportunities for teachers, like the American Chemical Society *Inquiry Matters,*[k] Although these workshops often offer depth of content and excellent instruction, they are usually residential programs, and require participants to travel and stay away from home.

The second type of workshop tends to be offered by publishers of competing curriculum products, and is focused more on how to use the materials provided in the curriculum package. These workshops seem to assume the teachers involved already have a mastery of the subject matter. Examples of this type of workshop are: *Counter Top Chemistry* and *Physics from the Junk Drawer,*[l] one day workshops offered by Science House; CPO Science on-site workshops in support of *Physics a First Course* and *Foundations of Physical Science;*[m] and PASCO[n] on-site workshops and summer institutes that focus on

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[h] Science Workshop for K-6 Teachers, Indiana University-Purdue University Fort Wayne, Division of Continuing Studies, 4 day, 8 hour/day, 3 credit workshop; http://www.ipfw.edu/dcs/workshops/summer.shtml#science

[i] Physics for Elementary Teachers, University of Colorado, Boulder, School of Education, 10 day, 7 hour/day, 3 credit workshop; http://www.colorado.edu/summersession/featured.html

[j] NSF Summer Institute in Physics and Physical Science For Inservice Teachers*,* University of Washington, Physics Education Group, 24 day, 6.5 hour/day, 10 credit workshop, http://www.phys.washington.edu/groups/peg/2006institute.html

[k] Inquiry Matters, American Chemical Society, http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=education\wande\OnlineCourse.html

[l] Counter Top Chemistry, The Science House, one day workshop, http://www.science-house.org/workshops/#desc

[m] Physics a First Course, CPO Science, customized on-site workshops, http://www.cpo.com/textbook.shtml

[n] PASCO Summer Institutes, http://www.pasco.com/training/institutes/home.html

integrating their sensors into curriculum. These programs are often sponsored by the local school district, and held in a local school. They take sometimes a single day, and seldom more than a weekend or a couple of days during the summer. Although they are convenient and palatable for teachers, they seldom offer real depth in the science content the curriculum covers. Some school systems offer local workshops targeting specific curriculum items; as an example, Montgomery County Public Schools, Rockville, Maryland offers one day elementary teacher training sessions[o] for science kits in Balls & Ramps, Balancing and Weighing, Sound, Electric Circuits, and Magnets & Motors. Although all of these workshops qualify in most areas as teacher professional development, their effectiveness in developing deep understanding of basic science concepts may be limited.

Developing a force and motion content workshop

With the workshops currently available in mind, what should an elementary teacher's force and motion workshop look like? MLR goals for elementary school students require teachers with a solid foundation in the basic concepts of force and motion. There is plenty of documentation in physics education research [Thornton and Sokoloff,[20] Dykstra,[38] Trowbridge and McDermott[13,19]], that shows "standard" (i.e. *lecture-based*) teaching techniques do not lead students to successfully acquire the knowledge their courses aim to impart. Instead it seems that an inquiry-based system, utilizing hands-on work and student exploration of the concepts, provides a deeper understanding of the

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[o] Elementary Science Unit Training, http://www.mcps.k12.md.us/curriculum/science/elem/unittrain.htm

ideas being learned [Hestenes et al.,[18] Minstrell,[3] Scott[41]]. It also seems that inquiry-based teaching provides the best opportunity for success with an in-service teacher development program. There are a number of curricula available to choose from in this area. *Physics By Inquiry*[42] is a well-respected curriculum with a rich research-based pedagogy. *Explorations in Physics*[43] and *Comprehensive Conceptual Curriculum for Physics* (C^3P)[44] both provide activity-based inquiry programs. The available programs are too numerous to completely list here. While most of these programs share similarities (inquiry-based learning, hands-on activities, small group learning) they often vary in the order of presentation, the topics covered, the depth of learning expected, and the equipment required.

The existence of "cross-cutting" standards in the MLR also suggests that teachers need to know more than just content material; it is at least as important for in-service teachers to extend their pedagogical content knowledge to include understanding their role in developing the language and resources that their students will need in future learning. This topic could easily be the subject of a semester-long course on its own, or even a life-long area of interest. Integrating enough content in this area to make a difference within the time limits of a concentrated workshop is difficult. There are prepared curricula that include epistemological development, however, they integrate it into a program intended to last an entire semester. An example of a curriculum in this group is *Physics for Elementary Teachers.*[45] Certainly any program intended to address deficiencies in teachers who will help develop student resource frameworks should include some explicit discussion of resources and frameworks. The overview provided by Redish[15] in his paper on modeling student thinking could provide a starting point. According to Redish, this paper *"… draw(s) from a variety of fields ranging from neuroscience to sociolinguistics to propose an over-arching theoretical framework that allows us to both make sense of what we see in the classroom and to compare a variety of specific theoretical approaches."* To a certain extent simply working through the inquiry program should model these ideas, but some explicit discussion of the topic should also be included. Lemke's[25] work on "talking science" could also be included as a valuable asset to a program aimed at getting teachers to do exactly that. Workshop facilitators should also be mindful of the epistemic frames that may be in use in this environment. Some frames are critical to success, both for teachers in a workshop and their students in later classroom situations. Tuminaro described three frames he felt were crucial in physics education;

- *Rote equation chasing* – students expect that problem solving in physics involves finding the right equation from many that are memorized, and plugging in the quantities from the problem.
- *Qualitative sense-making* – students expect that problem solving should progress through the systematic application of common sense or physical principles, and that formal mathematics is not required.
- *Quantitative sense-making* – similar to qualitative sense-making, but students expect to use formal mathematics.

Of these games, *qualitative sense-making* is the most productive in an elementary school environment. Elementary students are rarely exposed to the formal mathematics required to model many physical phenomena; that typically occurs in middle and secondary school classrooms. The work expected of elementary school students generally involves qualitative reasoning. The planned workshops should be centered in a *qualitative sense-making* frame where the participants will develop *"… the expectation that problem solving in physics should progress through the systematic application of common sense or physical principles."* The expectation is that they will then be able to model this behavior for their own students.

Many of the teachers involved will be from an older generation that is not fully comfortable with modern technology gizmos; use of low-tech teaching supports is appropriate when possible. As previously mentioned, some teachers feel that they are "not good" at the subject; reassuring them that the inquiry tasks are within their capability is important. As teachers are generally jealous of their free time, when possible workshops should meet them where they live, not force them to travel and stay away from home. The workshop setting should put them at ease – use of a school in their local area might be appropriate.

CHAPTER 5 – A CONCENTRATED ONE-WEEK SUMMER WORKSHOP

Curriculum

Early in 2005 we developed a curriculum package to present at a set of workshops planned for the summer of 2005. The choice of curricula was not easy. Several options seemed viable for this project. *Physics By Inquiry* (PBI),[42] *Explorations in Physics* (EIP),[43] and Physics for *Elementary Teachers* (PET)[45] all have research-based materials focusing on hands-on learning in an inquiry-based setting. In addition, the research programs and authors of these materials were known to the research team in this project, and it seemed portions of these programs could be made available for this work. We also reviewed *Inquiry Into Physical Science – The Automobile* (IIPS),[46] and *PRISMS-Plus*[47] as possible sources. The decision was made somewhat easier when we discovered that materials from the PET program could not be acquired in time to be effectively used for this project. PBI, EIP and IIPS all seemed to have similar materials in the force and motion area, but the EIP materials seemed to have a more conversational tone that the primary investigator felt would work better with the intended audience.

The curriculum as developed featured a hands-on inquiry-based program, and was intended to cover the concepts of velocity, acceleration, and force. The curriculum package prepared for the workshop attendees included all of EIP Unit A, with supplemental materials from a number of sources, including *Inquiry Into Physical Science – The Automobile.*[48] We also used a velocity lab from the introductory algebra-based physics course (PHY 111) at the University of Maine. A key component turned out to be the refining intuitions exercise, "*Dealing with counterintuitive ideas: Newton's 3rd law*"[49] developed by the University of Maryland.

As noted in previously, we felt that some work on teacher epistemologies was appropriate for these workshops. We planned each workshop day to open with a half-hour discussion of relevant topics in epistemology. These discussions were organized around four reading assignments, assigned at the end of each workshop day. The first reading, *Tapping Epistemological Resources for Learning Physics,*[14] was intended to introduce the concept of student resources, followed by the introduction and first chapter from *Talking Science: Language, Learning, and Values*[25]. The fourth session opened with discussion of *Understanding the Process of Students' Mathematics Use in Physics: An Introduction to Epistemic Games and Frames* (Chapter 5 in Tuminaro's Dissertation[24]), intended to introduce the concept of resource frameworks and how students use them. The last day of the curriculum opened with discussion of *Stop I Can't Fit Anything More into My Head: How Students Learn Physics,*[50] intended to tie resources, talking science, and resource frameworks together. The curriculum covered the following specific topics:

Velocity – velocity, speed, distance, time and their relationships; methods for graphical display of distance and velocity data; position/time graphs and use of motion sensors. This content area included a lab exercise that required participants to manually gather data, graph it, and report results to the entire workshop.

Acceleration – Effect of a push; slope of the velocity/time graph; effect of a constant force; strobe pictures of constant and accelerated motion; position/velocity/ acceleration graphs.

Forces – Gravity as a force; tossed and dropped (bouncing) ball; effect of multiple forces in two dimensions; demonstrations of inertia; Newton's laws; free body diagrams; friction; momentum.

Two reflection periods were also included during each day. Fifteen minutes during the lunch period were set aside for individual reflection, and the last half hour of the day was used to wrap up the days session and reflect on the work covered. Ten to fifteen minutes of this time was used in open discussion of the curriculum and it's applications to elementary school teaching. Each participant was asked to contribute during this period. The curriculum package as prepared proved to be very ambitious, and ultimately some of the sections were omitted. A copy of the schedule as actually presented is included as Appendix F.

Diagnostics

We selected three existing diagnostics to use in evaluating teacher response to the curriculum. We chose the Force and Motion Conceptual Evaluation (FMCE)[18] to evaluate content knowledge, the Maryland Physics Expectations Survey (MPEX)[60] to look at how the teachers viewed the process of teaching physics concepts, and the Science Teaching Efficacy Belief Instrument (STEBI)[51] to investigate outcome expectancy and self-efficacy as applied towards teaching science.

The FMCE was developed by Thornton and Sokoloff as a way to evaluate student understanding of basic force and motion concepts. It is a 47-question, multiple-choice evaluation, and is scored in five clusters. An overall score is also developed, but it does not include the Energy cluster (the four questions that make up this cluster are not considered to test force and motion concepts). The FMCE as used in this study is included as Appendix B.

The MPEX was, as the name suggests, developed at the University of Maryland. It is designed to evaluate student expectations towards learning physics in a classroom situation, so some questions were modified to reflect the expectations of teachers towards their students, and others were altered to reflect the workshop environment. The modifications were designed to retain the original intent of the questions in the new setting. For example, question 13 in the MPEX originally read, “My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it.” The word *learning* was substituted for *grade*, as there were no grades assigned in the workshop. A summary of the changes is included in Appendix C, along with a complete copy of the MPEX as used in this study. The evaluation as used here was a 29-question Likert-scale test. Both positively and negatively worded items are included. A score of 5 is assigned for both a “strongly agree” answer to a positively worded item and a “strongly disagree” answer to a negatively worded item. Similarly, “strongly agree” with a negatively worded item and “strongly disagree” with a positively worded item receive a score of 1. The MPEX is evaluated in six clusters and an overall score is also given. Table 5-1 below describes each of the clusters, and indicates the questions used to evaluate that cluster.

	Favorable	**Unfavorable**	**MPEX Items**
independence	learns independently, takes responsibility for constructing own understanding	takes what is given by authorities (teacher, text) without evaluation	7, 12, 13, 16, 25
coherence	believes physics needs to be considered as a connected, consistent framework	believes physics can be treated as separated facts or "pieces"	11, 14,15, 20, 27
concepts	stresses understanding of the underlying ideas and concepts	focuses on memorizing and using formulas	4, 13, 18, 22, 24, 25
reality link	believes ideas learned in physics are relevant and useful in a wide variety of real contexts	believes ideas learned in physics are unrelated to experiences outside the classroom	9, 17, 21, 23
math link	considers mathematics as a convenient way of representing physical phenomena	views the physics and the math independently with no relationship between them	2, 7, 14, 15, 16, 19
effort	makes the effort to use information available and tries to make sense of it	does not attempt to use available information effectively	6, 29

Table 5-1 – Clusters for dimensions probed by the MPEX Survey

The STEBI was developed by Riggs and Enochs[51] in 1990 as an extension of the earlier work by Bandura.[52] Their intent was “… to develop and partially validate a self-reporting elementary efficacy belief instrument.” The STEBI is a 25-question evaluation based using a Likert-scale format; the scoring is the same as the system used for the MPEX. A copy of the STEBI is provided in Appendix D along with a more detailed discussion of the instrument. The

STEBI is evaluated on two scales, Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). The PSTE includes 13 questions that evaluate how teachers view their own science teaching abilities, and the STOE includes 12 questions that look at whether teachers believe student learning can be influenced by effective teaching. PSTE and STOE scores are not combined for an overall score. Some researchers have found issues with the validity of the STOE construct, and even Riggs and Enochs noted that the STOE was not as reliable as the PSTE.

The Teachers

During the spring of 2005 we recruited two cohorts of teachers to participate in intensive one-week workshops designed to improve force and motion conceptual understanding. Recruitment was facilitated by offering a stipend and Continuing Education credits (which filled a professional development requirement for many of the teachers). Twenty elementary teachers in the area surrounding Sidney in central Maine volunteered, and another 12 signed up for a session in Presque Isle in northern Maine. (Note: three of the teachers originally scheduled for the Sidney offering did not attend for varying reasons.) The teachers covered all primary school grades, with 11 in Grades K-2, 12 in grades 3-4, and 5 in grades 5-6. Teaching experience ranged from two years to thirty years.

The Workshops

The Sidney workshop took place during five days at the end of June. The workshop was split by a weekend, Thursday, and Friday and Monday thru

Wednesday of the following week. Although the preferred arrangement was five consecutive days, many teachers found the split-week arrangement fortuitous as it allowed time for them to process the information they had encountered before continuing the curriculum the following week. The participants in Sidney elected to have an eight-hour day with a working lunch. Working straight through the day, even with participants able to get up and move around as needed, proved a bit much; many participants commented they needed down time to assimilate material. As a result, the Presque Isle session featured a half-hour break for lunch near mid-day, with about four hours of workshop time on either side. The Presque Isle workshop was held on five consecutive weekdays, about one month after the Sidney workshop. During the Sidney workshop two instructors were available to facilitate student learning each day, but in Presque Isle only one was available. However, with the reduced workshop size this seemed adequate to facilitate the three work groups used there. All three diagnostics were given as both pre- and post-tests, resulting in 29 matched pairs of data.

The Interviews

Approximately three weeks after each workshop we interviewed a group of the participating teachers. A total of eleven teachers participated, five from the Sidney workshop and six from Presque Isle. The interviews lasted about half an hour each, and consisted of two sets of questions. The first set consisted of five basic questions:

1. Did you find the workshop useful?
2. Can you think of any ways to improve the workshop?

3. Was the pace of the workshop appropriate?
4. Did you find the group work useful?
5. Was the instruction or facilitation adequate?

These questions were intended to gauge participant attitudes towards the workshop format and to seek ways to improve the workshop for any follow up offerings. The second set of questions dealt with specific physics situations, and was intended to gauge retention of workshop material during the three-week period between the interviews and the end of the workshop. The participants were asked to respond to the following situations:

1. A car or ball is given a push up a ramp. Describe the motion of the car (ball) from the time it leaves the hand pushing it up until it returns to the area of release using:
   a. Velocity
   b. Acceleration
   c. Force
2. Given a book lying on a table, describe the forces acting on the book.
3. Given a small car pushing a truck, discuss the force of the car on the truck vs the force of the truck on the car when:
   a. The truck is stopped, the car is pushing, but neither has started to move
   b. The truck and car are in contact and accelerating
   c. The truck and car are in contact and moving at a constant speed

d. The truck and car are in contact and the car is pushing, but the truck is applying its brakes to slow them both down.

Follow-up Survey

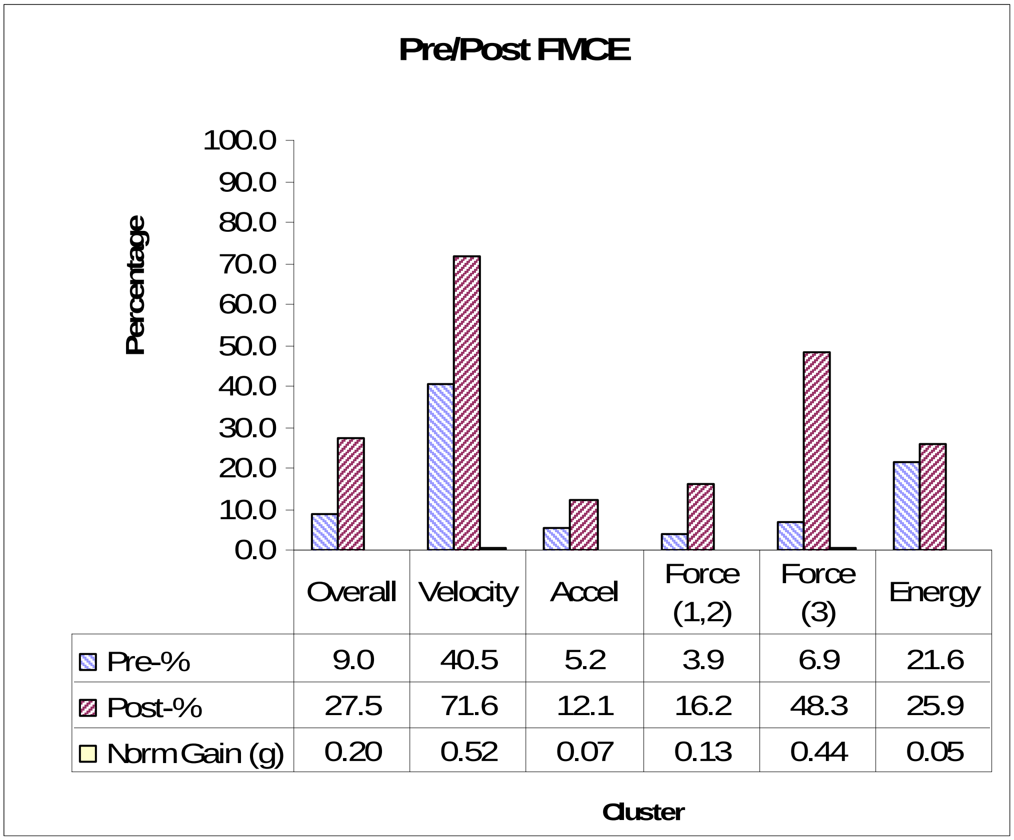
The original plan for this project included a follow-up survey near the beginning of calendar year 2006. The intent was to test for decay in the content knowledge and attitudes as measured by the diagnostics selected for this project. Materials, including copies of the FMCE, MPEX, and STEBI were sent to all of the workshop participants early in January of 2006. Unfortunately the return on this survey was not sufficient to draw statistically significant conclusions. No further time became available for this effort, and the follow-up survey was dropped from the project.

CHAPTER 6 – RESULTS

After a week of intensive learning, post-test scores show a definite gain in content knowledge and an improvement in attitude towards teaching and learning science. However, the content knowledge gains shown start from a fairly low baseline, and it appears that this workshop did leave all of the teachers fully ready to facilitate learning of the workshop content and the goals of the MLR.

FMCE Results:

The FMCE was scored using a template developed by Wittmann[53] using a rubric provided by Thornton. A detailed analysis of the FMCE data is in Appendix G, but Figure 6-1 summarizes the results. There was a clear and significant gain on the overall score, and in each of the clusters. A paired t-test indicated the results were significant at a 95% confidence level with $p = 6.25 \times 10^{-8}$ and $t = 1.70$. The Force (1,2) bar refers to questions dealing with Newton's first and second laws, while the Force (3) bar refers to Newton's third law questions. The pretest scores are low compared to other research using this diagnostic.[54, 55, 56, 57] However, most of the data available comes from studies in calculus based courses with students in engineering and science programs. We did not find any FMCE study data from in-service teacher cohorts. However, Pollock's[56] work includes discussion of a subgroup of students who were more heavily weighted towards women and non declared majors. This group had lower pretest and post-test scores, and also lower normalized gains. It is probably closer in makeup to the in-service teacher group discussed here. The average gain from our workshops is consistent with normalized gains seen by university physics students after a semester of traditional instruction.



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	9.0	40.5	5.2	3.9	6.9	21.6
Post-%	27.5	71.6	12.1	16.2	48.3	25.9
Norm Gain (g)	0.20	0.52	0.07	0.13	0.44	0.05

Figure 6-1 – FMCE Pre/Post-Test Results

The normalized gains on the Velocity and Force (3) clusters are much higher than the rest of the diagnostic. The average Velocity score for the post-test was over 70%, and 17 of the 29 participants scored 75% or more in this area. The average score on the Force (3) cluster was 48%, and 14 of the 29 participants scored at or above 67%; this showing is not quite as strong as the Velocity result, but still impressive given the short time spent in this area. We used a “refining intuitions” worksheet developed by the University of Maryland with the Newton’s

3rd Law material.[58] Other research at the University of Maine indicates that this worksheet is a powerful way to present this material.[59]

Tables 6-1 and 6-2 show more details of the FMCE results. Note that the zeroes in the “Min” line of the Tables do not indicate that any one person scored zero on all five clusters, they show that at least one person answered each of the questions in each of the clusters wrong. The overall minimum score increased to 9% from zero on the pretest.

According to Wittmann[53] 60% is “a threshold measure” that shows a minimum level of competence in any of the clusters.

	TOTALS		**CLUSTERS**				
	Values in # correct and % correct						
			Velocity	**Accel**	**Force (1,2)**	**Force (3)**	**Energy**
	#	**%**	**% Corr**	**% Corr**	**% Corr**	**% Corr**	**% Corr**
	33	**100**	**100**	**100**	**100**	**100**	**100**
Average	3.0	9.0	40.5	5.2	3.9	6.9	21.6
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	7.0	21.2	100.0	33.3	12.5	50.0	100.0
StDev	2.0	6.1	33.0	9.0	4.8	11.4	28.1
% above 60%		*0.0*	*27.6*	*0.0*	*0.0*	*0.0*	*10.3*
	N = 29		*All Cluster Values in % Correct*				

Table 6-1 – FMCE Pretest results

	TOTALS		**CLUSTERS**				
	Values in # correct and % correct						
			Velocity	**Accel**	**Force (1,2)**	**Force (3)**	**Energy**
	#	**#**	**% Corr**	**% Corr**	**% Corr**	**% Corr**	**% Corr**
	33	**33**	**100**	**100**	**100**	**100**	**100**
Average	9.1	27.5	71.6	12.1	16.2	48.3	25.9
Min	3.0	9.1	0.0	0.0	0.0	0.0	0.0
Max	21.0	63.6	100.0	66.7	56.3	100.0	100.0
StDev	4.1	12.6	28.9	16.0	14.7	34.0	25.4
% above 60%		*3.4*	*58.6*	*3.4*	*0.0*	*48.3*	*3.4*
	N= 29		*All Cluster Values in % Correct*				

Table 6-2 – FMCE Post-test results

MPEX Results:

A detailed analysis of the MPEX results can be found in Appendix H. A template prepared by Wittmann[53] was used to evaluate the MPEX results. A t-test using matched pair data at a 95% confidence level produced $p = 7x\ 10^{-6}$ with $t = 1.70$, indicating that the results are statistically significant. The template scores the MPEX data in six categories, plus an overall score. Of the five questions omitted from this offering of the MPEX, two (questions 33 and 34) are not normally scored by the template. The template required several minor modifications in order to remove the remaining three omitted questions from the evaluation. The results are shown in graphically in Figure 6-2 below. The vertical axis shows the percentage of favorable answers and the horizontal axes the percentage of unfavorable answers. A favorable answer is one that matches the sense of the question, agreeing with positively worded questions and disagreeing with negatively worded ones. A data point in the figure consists of both the favorable and unfavorable percentage for each category. Both pre- and post-test data are shown. One participant did not complete the last seven items on the post-test, so that data set is not included in the analysis, leaving 28 matched sets of data.

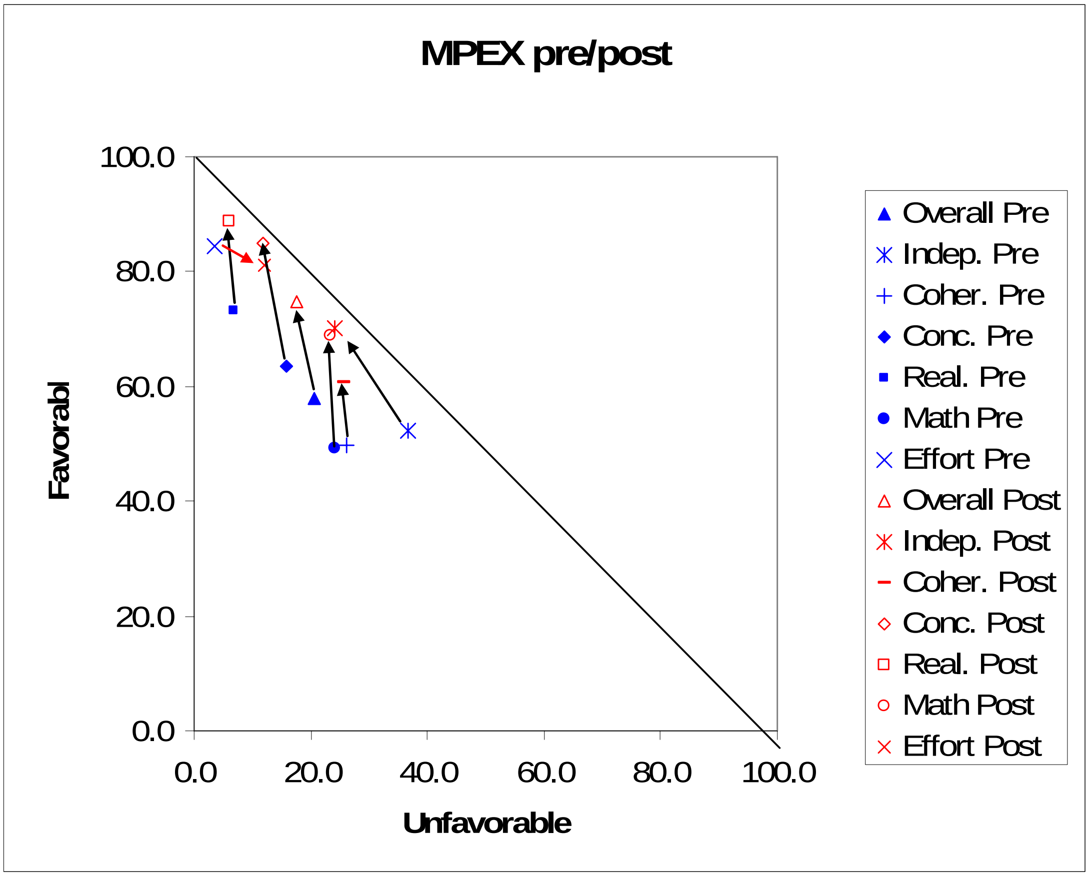


Figure 6-2 – **MPEX Pre- and Post-Test Results**

The results are also shown in Table 6-3. The workshop teachers showed significant improvement on the overall score and five of the six dimensions. The sixth dimension, Effort, is probably unreliable as three of the five questions that make up the category were deleted in this offering of the MPEX. In addition, the team who developed the MPEX considered this the weakest of the scores. We do not discuss Effort results any further. The following statement appears on the MPEX home page:

"Note that the items of the effort cluster consistently show a strong decline arising from a comparison of "pre-course optimism" and "post-course reality checks." Many students intend the activities inquired about in our effort items but in the press of time do not actually carry them out. Although we find these items interesting and revealing, unless these are a primary focus of your course we do not recommend including them in the overall MPEX score."

pre			post			
Cluster	**Status**	**Score**	**Cluster**	**Status**	**Score**	**St Gain**
Overall Pre	favorable	58.9	Overall Post	favorable	71.7	0.31
	unfavorable	19.8		unfavorable	21.7	0.02
Indep. Pre	favorable	53.6	Indep. Post	favorable	72.0	0.40
	unfavorable	35.1		unfavorable	22.6	-0.19
Coher. Pre	favorable	50.7	Coher. Post	favorable	61.4	0.22
	unfavorable	25.7		unfavorable	25.7	0.00
Conc. Pre	favorable	64.3	Conc. Post	favorable	87.1	0.64
	unfavorable	14.3		unfavorable	9.3	-0.06
Real. Pre	favorable	74.1	Real. Post	favorable	91.1	0.66
	unfavorable	5.4		unfavorable	4.5	-0.01
Math Pre	favorable	50.9	Math Post	favorable	71.4	0.42
	unfavorable	22.3		unfavorable	20.5	-0.02
N =	28					

Table 6-3 – MPEX Results, Favorable vs Unfavorable Responses

In general, the results show a group of teachers whose expectations about teaching and learning physics improved significantly during the week of the workshop. Normalized gains for the overall and each cluster were high and positive for the favorable responses, and all of the clusters had very low or negative gains for the unfavorable responses.

The post-test results are higher than those reported by Redish et al.[60] for undergraduate physics students at a variety of different universities. Also, in most of the cases provided by Redish et al. the scores actually decreased following instruction.

Table 6-4 shows the data broken into groups representing the top, middle, and bottom third of the workshop data, sorted by MPEX post-test score. The data shows that all three groups improved, but that the improvement for the bottom group is significantly less. In the case of the Coherence and Math Link clusters the number of unfavorable responses actually increased, although the favorable responses increased as well. These clusters are shown graphically in Figures 6-3 and 6-4. The other three clusters are shown with similar figures in Appendix H. Note that the post-test scores for the low group nearly evenly split between favorable and unfavorable for the Independence, Coherence, and Math Link clusters, and that the scores for this group are significantly lower in favorable responses and higher in unfavorable responses than the rest of the participants.

Pre-Test Data						Post-Test Data					
Cluster	Status	Score	Top	Mid	Low	Cluster	Status	Score	Top	Mid	Low
Overall	fav	58.9	70.0	60.5	44.8	Overall	fav	76.6	88.3	77.0	63.2
	unfav	19.8	14.5	14.2	31.4		unfav	16.3	6.9	14.6	28.4
Indep.	fav	53.6	66.7	59.3	33.3	Indep.	fav	72.0	95.0	74.1	44.4
	unfav	35.1	18.3	27.8	61.1		unfav	22.6	5.0	20.4	44.4
Coher.	fav	50.7	58.0	55.6	37.8	Coher.	fav	61.4	76.0	62.2	44.4
	unfav	25.7	22.0	20.0	35.6		unfav	25.7	16.0	15.6	46.7
Conc.	fav	64.3	74.0	71.1	46.7	Conc.	fav	87.1	98.0	84.4	77.8
	unfav	14.3	12.0	4.4	26.7		unfav	9.3	0.0	11.1	17.8
Real.	fav	74.1	87.5	72.2	61.1	Real.	fav	91.1	100.0	91.7	80.6
	unfav	5.4	0.0	2.8	13.9		unfav	4.5	0.0	2.8	11.1
Math	fav	50.9	67.5	41.7	41.7	Math	fav	71.4	82.5	80.6	50.0
	unfav	22.3	12.5	19.4	36.1		unfav	20.5	10.0	13.9	38.9
N=	28	fav = favorable		unfav = unfavorable							

Table 6-4 – MPEX Clusters by High, Middle, and Low Third Groups

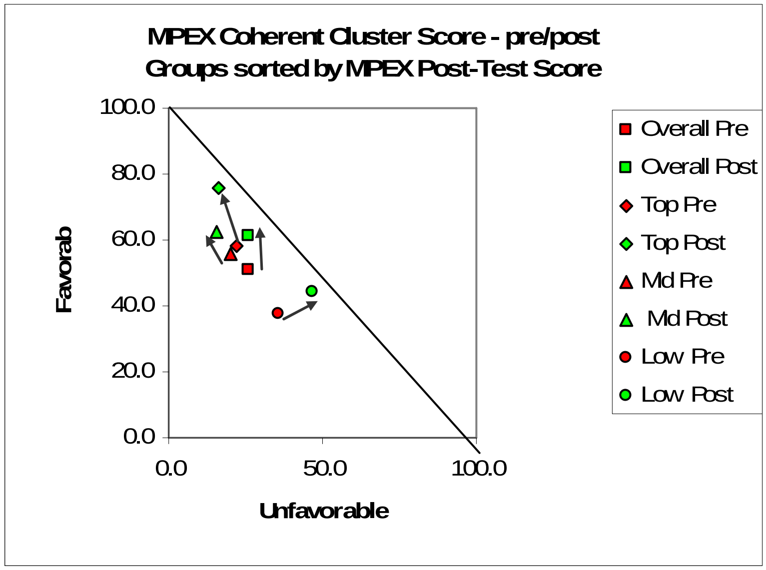


Figure 6-3 – MPEX Coherence Cluster, Low, Middle, and High Groups

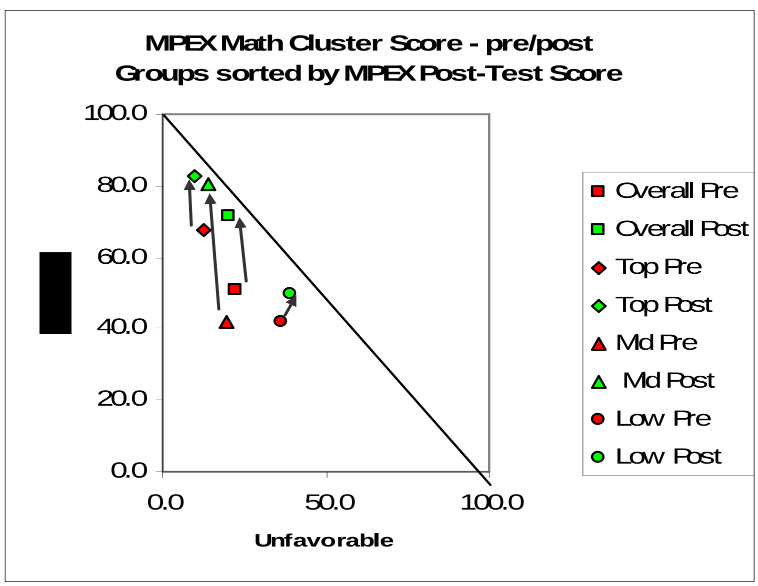


Figure 6-4 – MPEX Math Link Cluster, Low Middle and High Groups

STEBI Results

As devised by Riggs and Enochs[51] the STEBI is normally evaluated on two constructs based on a five point Likert scale. The two constructs are Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE). A detailed analysis of the STEBI results is included in Appendix I, however, our results show pre and post-test scores with little change, especially on the STOE construct, when using the scoring method devised by Riggs and Enochs. T-tests of the paired results showed these results are not statistically significant. Riggs and Enochs found that the STOE construct was less reliable than the PSTE, and Roberts et al.[61] found problems with the STOE construct, noting that they felt it should not be used to evaluate teacher efficacy. They felt that the STOE more properly evaluated teachers' feelings towards how much control they have over their teaching situation. Many of the teachers involved in these workshops complained that their school administrations allowed them very little opportunity to affect the material covered in their classrooms, and required them to present a great deal of material with very little depth. This seems to agree with the analysis of Roberts et al.

We modified the scoring to use the system devised by Wittmann for evaluating the MPEX. Favorable responses (favorable responses are those that agree with a positively worded question or disagree with a negatively worded question) receive a score of positive one, zero is assigned for responses of Uncertain, and negative scores correspond to unfavorable responses. This system reduces the variability due to slight changes in how questions are interpreted day-to-day, and also eliminates some of the variability of interpretation of the meaning of “strongly agree” and “strongly disagree.” It also allows analysis of both the favorable and unfavorable responses, and tracking of the change from unfavorable to favorable, and vice versa.

Pretest					
Scale	**Status**	**Score**	**Top**	**Mid**	**Low**
STOE	favorable	65.5	61.4	67.6	62.0
	unfavorable	15.8	15.2	18.5	13.0
PSTE	favorable	70.8	91.6	85.5	25.6
	unfavorable	14.9	2.8	5.1	33.3
Post-Test					
Scale	**Status**	**Score**	**Top**	**Mid**	**Low**
STOE	favorable	66.7	64.4	62.0	69.4
	unfavorable	14.9	12.9	16.7	13.9
PSTE	favorable	79.8	97.9	87.2	42.7
	unfavorable	9.0	0.0	6.0	20.5
Total N = 29; Top N = 11; Mid N = 9; Low N = 9					
Percent of possible score, groups sorted by PSTE post-test score					

Table 6-4 – STEBI Top, Middle, and Low Third Scores

Using the revised scoring we still found the STOE results inconclusive. There was very little variation from the pre- to the post-test and very little correlation with the other diagnostics used. The results for the PSTE were more interesting, especially when the participants were divided into a low, middle, and high group based on their PSTE post-test results. We found significant differences in the scores of the three groups, and a much larger improvement in the lower group. Table 6-4 below shows the results of the STEBI, the values shown are percent of possible score. This information is also shown graphically in Figure 6-4 below. The top group has 11 members with scores 12 or higher out of a possible 13, the middle and low groups have 9 members each. Care should be used in looking at the Low group improvement, however. Four of the members of this group had improvements of 10 points or more, the remaining five members averaged a loss of a little less than one point.

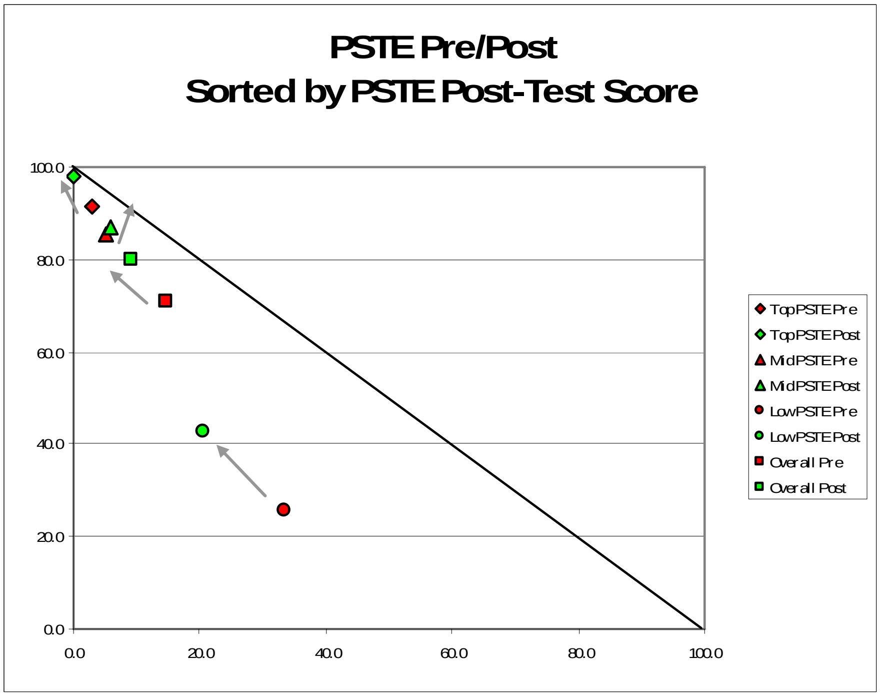


Figure 6-4 – STEBI PSTE Score Movement, Top, Middle, and Low Third Groups

The results of several questions are also of interest. Table 6-5 below shows the results of these questions. The first number in each pair is the number of favorable responses, the second is the number of unfavorable responses. N=29 for the entire data set, including both workshops, N=11 for the high group, N=9 for the low group. PSTE after the question indicates a question on the PSTE scale, and STOE indicates a question on that scale. Generally these results show higher scores in the favorable category and lower scores in the unfavorable category. Two of the questions reverse that trend, # 3 and # 8. These results will be discussed in the Discussion section.

		Overall		High		Low	
Q #	Question	Pre	Post	Pre	Post	Pre	Post
3	Even when I try very hard, I don't teach science as well as I do most subjects ***PSTE***	16, 9	13, 9	11, 0	10, 0	0, 8	1, 7
5	I know the steps to teach science concepts effectively ***STOE***	16, 6	21, 0	8, 1	11, 0	2, 5	4, 0
8	I generally teach science ineffectively ***PSTE***	24, 0	20, 5	11, 0	11, 0	4, 0	2, 3
10	The low science achievement of some students cannot generally be blamed on their teachers. ***STOE***	7,13	9,17	3,5	3,7	3,1	3,5
15	Students' achievement in science is directly related to their teacher's effectiveness in science teaching ***STOE***	13, 6	21, 2	3, 3	7, 1	4, 1	8, 0
17	I find it difficult to explain why science experiments work ***PSTE***	18, 6	23, 1	10, 0	11, 0	2, 4	3, 1
21	Given a choice, I would not invite the principal to evaluate my science teaching ***PSTE***	18, 11	23, 5	8, 3	10, 0	1, 8	4, 5

Table 6-5 – Results for selected STEBI Questions

Note: The first letter in each pair is the number of favorable responses to the question, the second is the number of unfavorable responses. N=29 Overall, N=11 High, N=9 Low

Correlations Between Diagnostics

A complete tabulation of correlations between the various diagnostics is included in Appendix K. Although there are many interesting correlations between these evaluation items, those that are of interest here compare attitudes and expectations prior to the workshop with those after the workshop, those that relate the attitudes and expectations with performance on the FMCE, and those that relate performance on one aspect of the FMCE with the performance on another aspect of the same diagnostic.

There are several items that we will not discuss here:

1. The FMCE Acceleration and F 1,2 scores were uniformly poor, both on the pre- and post-tests, as were the scores on the overall pretest. We feel there are no meaningful correlations to be made with these results.

2. Energy was not a curriculum item in this project, and is not a force and motion concept, so the FMCE Energy cluster will not be used in discussion of correlations.

3. As noted in the STEBI Results section above, previous research has shown that the STOE construct has potential flaws. We don't feel the data available in this project is sufficient to draw meaningful correlations using this construct.

4. We do not consider correlations between the MPEX Effort cluster and other constructs. This cluster is normally the weakest of the MPEX

items, and in this case has been reduced to only two viable test items. We do not feel the remaining data provides meaningful correlations

That leaves comparisons between the PSTE pretest, post-test, and gain and the MPEX and its clusters, and between the FMCE and its clusters and the MPEX and clusters. Table 6-6 below gives the correlation coefficients for the various combinations.

STEBI / *MPEX and FMCE Post Cluster*	*PSTE Pre*	*PSTE Post*	*PSTE Gain*	*FMCE Post*	*FMCE Norm Gain*	*FMCE Velocity*	*FMCE F3*
MPEX Pre	0.51	0.32	-0.45	0.41	0.35	0.27	0.15
MPEX Post %	0.49	0.57	-0.11	0.45	0.40	0.50	0.22
MPEX Gain	-0.40	-0.31	0.30	-0.38	-0.36	-0.45	-0.25
MPEX Norm Gain	0.12	0.37	0.29	0.04	0.04	0.32	0.03
MPEX Indep	0.51	0.45	-0.28	0.35	0.25	0.39	0.21
MPEX Coherence	0.34	0.35	-0.13	0.53	0.53	0.45	0.40
MPEX Concepts	0.31	0.54	0.17	0.28	0.28	0.32	0.13
MPEX Reality	0.11	0.11	-0.05	0.33	0.24	0.39	0.11
MPEX Math	0.61	0.62	-0.23	0.19	0.19	0.24	-0.08
FMCE Post	0.09	0.07	-0.06				
FMCE St Gain	0.13	0.18	0.00				
FMCE Velocity	0.43	0.36	-0.26				
FMCE F3	-0.06	-0.09	0.00				

Table 6-6 – Correlations Between Diagnostics

None of these combinations yields a very large coefficient. We investigated some of the combinations with the highest values, but did not find any that produced interesting relationships. The most promising combination appeared to be PSTE Post-test and MPEX Math cluster (highlighted in table 6-6). When the MPEX math scores are sorted by PSTE Post-test score they do indeed show a trend for higher scores near the top, and lower scores near the bottom. However the trend is not strong; there are very low scores near the top, and

100% scores near the bottom. Note also that both the MPEX and the STEBI carry warnings that caution using them to evaluate individuals. This “product warning” from the MPEX website illustrates this issue:

> *“Note that individual items from this survey should not be used to evaluate individual students. On any single item, students may have atypical interpretations or special circumstances which make the "non-expert" answer the best answer for that student. Furthermore, students often think that they function in one fashion and actually behave differently. For the diagnosis of the difficulties of individual students more detailed observation is required. This survey is primarily intended to evaluate the impact of one or more semesters of instruction on an overall class. It can be used to illuminate some of the student reactions to instruction of a class that are not observable using traditional evaluations. In this context, it, together with evaluations of student learning of content, can be used as a guide for improving instruction.”*

Interview Results:

Eleven teachers were interviewed following the workshops. Ten of the interviews were videotaped; the eleventh video was lost due to technical difficulties with the recording equipment and only brief field notes are available. In general the results reveal teachers who felt the workshop was useful and that gains made in the workshop were retained.

General Workshop questions:

Many of the participants felt that the workshop provided too much information too fast. Several commented that spreading the workshop over a longer period of time would help them better integrate the information. Most of these also commented that getting teachers to give up more time for this kind of workshop would be difficult, if not impossible. When asked specifically about the pace, however, participants almost uniformly said the pace was appropriate for the audience and material. This contrasts with the opening comment in this section. The participants felt that group work was effective for this kind of learning. Many were frustrated by the lack of intervention from the facilitators, although most realized that making them work through their own problems was a more effective learning process.

Force and motion content questions:

We analyzed the video records from the interviews, and compared the conceptual knowledge demonstrated with the results from the post-test FMCE cluster scores. In general it appeared the participants had retained the material they had learned in the workshop, although one participant demonstrated a slight deterioration in velocity knowledge and another demonstrated a deterioration of Newton’s 3rd resources. There were two cases where participants showed force resources that the FMCE didn’t record, and a third who demonstrated better acceleration resources than the FMCE predicted. A synopsis of each interview along with a comparison to the FMCE results is at Appendix F.

CHAPTER 7 - DISCUSSION

The participants were in general agreement that the workshop was useful and that it would help them better present force and motion materials to their classes. The data indicate that their content knowledge has improved, as have their attitudes and beliefs about science teaching. However, those gains don't necessarily result in teachers fully prepared to facilitate learning of the goals presented by the MLR and NSES. Below we present discussion of the results from the various components of this project.

Force and Motion Content

Although most of the participants showed significant improvement in their FMCE scores, those scores still remained lower than most experts would deem adequate to properly facilitate learning. Only two of the participants scored more than 50% overall on the post-test, and almost half were below 60% on the velocity cluster, the area of best performance on the content diagnostic (according to Wittmann[53] 60% is the threshold considered by many to represent minimum mastery of the FMCE content material). The results of the FMCE show that the original premise, that the general pool of elementary teachers is not prepared to teach basic concepts in Force and Motion, is valid. The highest pretest score on this diagnostic was 21%, and the average was only 9%.

The improvement after the workshop is encouraging, but the final average of 27% doesn't instill a great deal of confidence that this workshop as presented can achieve the goal of preparing in-service teachers to facilitate the learning envisioned by the MLR and NSES. Pollock[56] found an average pretest score of 29.6% in a large calculus-based undergraduate course, but noted that female scores were over 10% below the norm. However, within this same population he found a group of students who made up the lower end of the class in post-test performance. This group had a higher ratio of female students, and a higher ratio of undeclared majors. Their average pretest score of 13% and demographic align them more closely with our workshop participants. This group achieved a normalized gain of 0.18, and the graphical results indicate a post-test average in the neighborhood of 30%. All of this data points to similar performance from a semester long course compared to our results.

The post-test scores on the velocity cluster indicate that these teachers may be ready to facilitate learning of velocity concepts at the elementary school level, but additional work would be necessary for most of this group to effectively teach acceleration and force concepts. This result should be hardly surprising given the general lack of prior physics training. Most of the teachers who participated in the interviews commented that the curriculum presented too much material to fast. Although participants were given all the time they needed to work through the curriculum material, many felt pressured to move forward and "keep up." This may have contributed to less than optimal retention of the material.

Attitudes and Expectations

The STEBI and MPEX results are encouraging, in that they show a cadre of teachers who are beginning to realize some of the deficiencies in their backgrounds, and a willingness, and even desire, to improve their teaching abilities in this area. However, the reality of fitting the required training into a busy teaching schedule may make that difficult.

MPEX

The MPEX results are extremely encouraging in most respects. The pretest levels of these teachers exceeded those of the undergraduate physics students at several major universities as reported by Redish et al.[60] It is also interesting to note that our results showed improved attitudes overall and in all of the clusters, while many of the university classes showed decreases. A possible explanation for this phenomenon is that our population consisted of experienced teachers who by and large understand the requirements for teaching in general and can apply them to science. Their improvement may also be due to our explicit discussion of the relationship of science learning and attitudes during the workshop. Although our results show strong improvement and favorable scores on all five clusters, these improvements are not nearly as pronounced for those participants scoring near the bottom of the group when sorted by MPEX post-test score. This effect is especially noticeable in the Independence, Coherence, and Math Link clusters, where the bottom third of the group is nearly evenly split between favorable and unfavorable responses. It appears there is a subset of these teachers who may have a view of physics more in line with the unfavorable view given in Table 5-1, that is, teachers who:

1. take what is given by authorities (i.e. the curriculum they are learning from and probably those they are teaching from) without evaluation

2. believe physics can be treated as separated facts or “pieces”
3. view the physics and the math independently with no relationship between them

Sorting answers into favorable and unfavorable categories also allows analysis of individual question responses. Most of the questions in this offering of the MPEX resulted in improvement, that is, more favorable responses and fewer unfavorable ones. There are a few questions that don’t follow this mold. Question 10 states “A good understanding of physics is necessary for me to achieve my career goals.” On the pretest there were 5 favorable and 9 unfavorable responses, on the post it was 5 and 15. The increase in unfavorable responses came predominantly from the upper and middle groups. This would seem to indicate that many of these teachers changed their opinion on how valuable the content presented would be in their classrooms. This is a disturbing concept, and one that could use additional research. However, the rest of the MPEX results don’t seem to corroborate that result. Question 15 is another item with an increase in unfavorable responses, but this one seems to have a more straightforward explanation. The test item says *“The derivations or proofs of equations has little to do with solving problems or with the skills I need to successfully understand physics.”* This workshop spent very little time in deriving equations, and not much in actually solving traditional problems. It is easy to see why these teachers might feel that those are not very important skills.

STEBI

Teacher's self-efficacy can be defined as the belief that one's teaching ability is related to positive changes in student attitudes, behaviors, and achievement. The STEBI is intended to measure self-efficacy as it relates to science teaching. Our results show that these teachers started the workshop with slightly lower scores than Riggs and Enochs[51], but consistent with the scores found by Roberts et al.[61] Research has found the STOE construct unreliable, but the PSTE has proven useful. Roberts et al. report that teachers with high PSTE scores reported liking science activities more often than their lower scoring peers, and that they found personal relevance in science. They were also more likely to spend the time needed to develop science concepts in their classrooms.

A couple of the questions from the STOE may illustrate some of the problems there. Question 10 had a very poor result, but the statement *"The low science achievement of some students cannot generally be blamed on their teachers"* may have been misinterpreted by these teachers. Question 10 received 17 unfavorable responses on the post-test, including 7 from the high PSTE group. These results here are not consistent with the results on question 15, which made a similar statement *"Student's achievement in science is directly related to their teacher's effectiveness in science teaching."* Question 15 received 21 favorable responses, and only 2 unfavorable. Seven of the high PSTE group gave favorable responses, and only one had an unfavorable response.

Our results show a majority of our teachers with fairly high efficacy ratings, and with PSTE scores that improved in general. However, we found a grouping at the bottom of the PSTE scores who were significantly lower in their efficacy ratings than their peers. Questions 3 and 8 are indicative of this trend. Question 3 stated, *"Even when I try very hard, I don't teach science as well as I do most subjects."* On the pretest 16 of the teachers disagreed with this statement and 9 agreed – including 8 of the 9 teachers in the low PSTE group. On the post-test the number disagreeing with the statement dropped to 13, but 10 of those were in the high PSTE group. Of the 9 who still agreed, 7 were from the low PSTE group. Question 8 stated, *"I generally teach science ineffectively."* There were no teachers who agreed with this statement on the pretest, and all 11 of the high PSTE group disagreed. In the low PSTE group there were 3 teachers who agreed with this statement on the post-test, and five overall. This may have been due to a realization that they had not previously been very effective, and that there may be work to be done in becoming effective. However it is difficult to draw inferences with a data set of only five teachers.

It is important to note that the low PSTE group also showed the strongest gains in PSTE scores, possibly a result of the explicit coverage of science teaching efficacy topics during the workshop. It is likely that some of these teachers may elect to take more time for science teaching in the future, and that they may become more effective science teachers in spite of their lower scores. Question 21 from the STEBI may be particularly indicative of this. The question reads, *"Given a choice, I would not invite the principal to evaluate my science* *teaching."* Initially eleven of the teachers agreed with this statement, including three from the high PSTE group. On the post-test only five agreed with the statement, and all were from the low PSTE group; that group had also improved from eight teachers who would not invite the principal, to five.

Workshop format

This workshop does not seem to have been sufficient to adequately cover all of the intended material. A possible improvement would be to extend the workshop time, to spend two weeks or longer in working on these concepts. However, the workshop would then begin to look like a regular university class, and that might make teachers less receptive to using this kind of tool. Another possible improvement would be to break the workshop into two, or possibly three individual workshops. That would maintain the compressed workshop feel, and would allow the participants to spend more time internalizing the material. However, it would then require them to complete a series of workshops in order to gain mastery of the subject material. While this might be acceptable to some, others would find it difficult to find the time on a repeated basis. In addition, there could be problems with retention of material from one workshop to the next.

Implications for Professional Development

There are many workshops provided to teachers these days in the name of professional development, more so with the additional requirements for "Highly Qualified" teachers under the No Child Left Behind law. Many of these workshops attempt to cover more material in less detail than the workshop conducted in this research project. Given the results of this workshop, it might be beneficial for further research to look at the effectiveness of those workshops as well. It may be that changes are needed in the professional development of our elementary teachers.

Force and motion is a small portion of the NSES and the MLR. The breadth of material the standards expect to be covered in our school systems is truly amazing. Requiring teachers to be experts in all of the facets of learning we want and expect to have covered may be stretching their abilities. Another possible solution might be to utilize science specialists, who would receive more intensive training before certification to teach, or would acquire the additional training prior to being named a specialist. These teachers could then move from class to class, much as music and art teachers do currently, covering the bulk of the science curriculum. This already happens in some schools. We have talked with several teachers who noted that when they had several teachers assigned to the same grade in their school it was not unusual for the one with the strongest science background to take over the science curriculum for all, with the other teachers filling in the gaps in other subjects.

L.C. McDermott[62] pioneered another method for developing the necessary science skills at the University of Washington. The program there consisted of training individuals or groups of teachers in depth (a summer institute full days for eight weeks plus additional weekly training over the following school year) who then served as training “instructors” for other teachers in their school districts. The process required extensive buy-in from administrators and school boards, and dedication of school resources, including teacher time, to the project. When properly implemented the program paid significant dividends – but McDermott found that it was easy for these schools to fall back to previous positions without constant vigilance. If the support can be provided by local school authorities, a potential source of these “trainers” could be the science teachers from the local middle and high schools. Individuals who are already required to have a fairly deep understanding of the sciences, and who should have a vested interest in the quality of students coming up through their districts elementary schools.

CHAPTER 8 - CONCLUSIONS

Teaching to the goals of the NSES and state learning standards for physics and physical science should provide elementary students with the beginnings of a solid framework for understanding the world. This requires that elementary teachers enter their classrooms with the same framework themselves. For the topics of kinematics and dynamics, a Newtonian framework is necessary for a complete conceptual understanding. Our evidence and previous work indicate that most elementary teachers lack a Newtonian framework, and are therefore under-prepared to teach this model in the classroom. Professional development opportunities exist to improve teacher conceptual understanding. Our research results suggest some important guidelines for design of in-service professional development workshops, at least in the realm of forces and motion.

First, content must be pared to a level that the workshop participants can handle in a meaningful way. Adding more material does not in any way guarantee more learning. Successful workshops should include inquiry-based curricula for physics concepts as well as discussion of the ideas of resources and the part that language plays in the developing resource frameworks of elementary school students. Both of these components are necessary for the teachers to fully experience inquiry themselves and to discuss the implications of research on how learning occurs in children. This aspect of the experience further restricts the amount of content coverage. Importantly, care must be taken to ensure that the desired improvements are actually taking place, by means of assessment of teacher conceptual and epistemological development. In this way, workshops for in-service elementary teachers may prove to be both a palatable and effective way to improve both content knowledge and science teaching self-efficacy of these teachers. There is evidence that self-efficacy is a necessary but not sufficient condition for effective science teaching,[61] so this aspect of professional development should not be neglected.

Although our teachers liked the workshop and felt it left them better prepared to teach force and motion in their classrooms, our workshop was not successful in preparing all of the participants to facilitate learning of the force and motion material covered. However, it did create a significant, albeit localized, improvement in the content knowledge of the participants. Furthermore, the participating teachers realized significant gains in attitudes about learning and teaching science in the workshop with a relatively small emphasis on epistemology and learning theory.

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APPENDICES

Appendix A – The Maine Learning Results, Section I. - Motion

I. MOTION

Students will understand the motion of objects and how forces can change that motion. Students will be able to:

ELEMENTARY GRADES Pre-K-2

1. Develop a variety of ways to describe the motion of an object.
2. Demonstrate that the motion of an object can be changed.

EXAMPLE

- Describe the motion of an object using terms such as forward, backward, straight, zigzag, up, down, fast, slow, etc.

ELEMENTARY GRADES 3-4

1. Describe the effects of different types of forces (e.g., mechanical, electrical, magnetic) on motion.
2. Draw conclusions about how the amount of force affects the motion of more massive and less massive objects.
3. Generate examples illustrating that when something is pushed or pulled, it exerts a reaction force.

MIDDLE GRADES 5-8

1. Describe the motion of objects using knowledge of Newton's Laws.
2. Use mathematics to describe the motion of objects (e.g., speed, distance, time, acceleration).
3. Describe and quantify the ways machines can provide mechanical advantages in producing motion.

SECONDARY GRADES

1. Use mathematics to describe the law of conservation of momentum.
2. Explain some current theories of gravitational force.
3. Use Newton's Laws to qualitatively and quantitatively describe the motion of objects.
4. Describe how forces affect fluids (e.g., air and water).
5. Explain the relationship between temperature, heat, and molecular motion.
6. Describe how forces within and between atoms affect their behavior and the properties of matter.

EXAMPLE

- Investigate and describe the motion of an amusement park ride.

Proposed Revised Maine Learning Results for Science and Technology

03/30/2006 DRAFT DOCUMENT

D. THE PHYSICAL SETTING - Students will understand the universal nature of matter, energy, force and motion, and will be able to identify how these relationships are exhibited in Earth Systems, in the solar system and throughout the universe.

PK - 2

D4 Students will describe the motion of objects and ways to make objects move in different ways.

a. Describe different ways things move and what it takes to start an object moving or to keep objects going.
b. Give examples of things that make sound by vibrating.
c. Give an example of how Earth makes things move.

Grades 3-5

D4 Students will summarize how various forces affect the motion of objects.

a. Predict the effect of a given force on the motion of an object.
b. Describe the relationship between how fast things move and how long it takes them to go a certain distance.
c. Give examples of how gravity, magnets, and electrically charged materials push and pull objects.

Grades 6-8

D4 Students will describe the nature of light, the motion of waves and the force of gravity.

a. Describe the kind of motion that sound, and light waves have in common, and how their motions are different.
b. Explain the relationship between visible light, the electromagnetic spectrum and sight.
c. State what determines the strength of the gravitational force between any two objects and the effects on the solar system.
d. Explain that electric currents and magnets exert force on each other.
e. Describe the effects of different types of force on an object.

Grades 9-Diploma

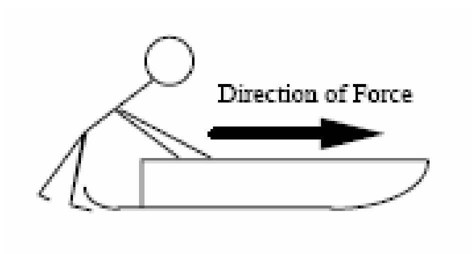
D4 Students will understand that the laws of forces and motion across the universe.

a. Describe the intellectual developments that have led to our present understanding of the universe structure and motion.
b. Describe Newton's concept of universal gravitation, using the motion of galaxies, stars, planets, moons, comets, and various events on Earth as examples.
c. Describe the idea of an expanding universe and the concept used by scientists to explain it.
d. Describe the contribution of Newton to our understanding of force and three laws of motion.
e. Explain the ideas of relative motion and frame of reference.
f. Describe some of the conceptual considerations in modern technologies that are based on the interplay of magnetic and electric forces.
g. Explain the relationship between stars and nuclear energy.

Appendix B – The Force and Motion Conceptual Evaluation

Directions: Answer questions 1-47 in spaces on the answer sheet. Be sure your name is on the answer sheet. <u>Answer question 46a also on the answer sheet</u>. Hand in the questions and the answer sheet.
A sled on ice moves in the ways described in questions 1-7 below. Friction is so small that it can be ignored. A person wearing spiked shoes standing on the ice can apply a force to the sled and push it along the ice. Choose the one force (**A** through **G**) which would **keep the sled moving** as described in each statement below.

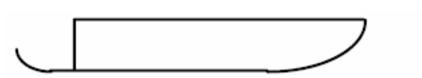
You may use a choice more than once or not at all but choose only one answer for each blank. If you think that none is correct, answer choice J.



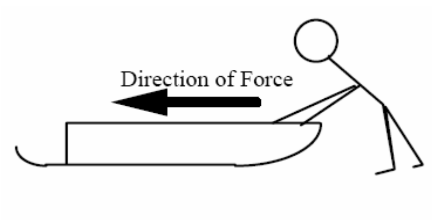
A. The force is toward the **right** and is **increasing** in strength (magnitude).

B. The force is toward the **right** and is of **constant** strength (magnitude).

C. The force is toward the **right** and is **decreasing** in strength (magnitude).



D. No applied force is needed



E. The force is toward the **left** and is **decreasing** in strength (magnitude).

F. The force is toward the **left** and is of **constant** strength (magnitude).

G. The force is toward the **left** and is **increasing** in strength (magnitude).

____1. Which force would keep the sled moving toward the right and speeding up at a steady rate (constant acceleration)?

____2. Which force would keep the sled moving toward the right at a steady (constant) velocity?

____3. The sled is moving toward the right. Which force would slow it down at a steady rate (constant acceleration)?

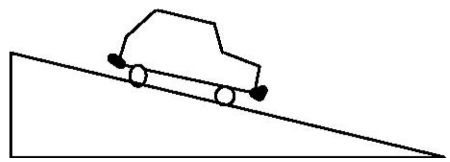
____4. Which force would keep the sled moving toward the left and speeding up at a steady rate (constant acceleration)?

____5. The sled was started from rest and pushed until it reached a steady (constant) velocity toward the right. Which force would keep the sled moving at this velocity?

____6. The sled is slowing down at a steady rate and has an acceleration to the right. Which force would account for this motion?

____7. The sled is moving toward the left. Which force would slow it down at a steady rate (constant acceleration)?

Questions 8-10 refer to a toy car which is given a quick push so that it rolls up an inclined ramp. After it is released, it rolls up, reaches its highest point and rolls back down again. *Friction is so small it can be ignored.*



Use one of the following choices (**A** through **G**) to indicate the **net force** acting on the car for each of the cases described below. Answer choice **J** if you think that none is correct.

(A) Net **constant** force **down** ramp
(B) Net **increasing** force **down** ramp
(C) Net **decreasing** force **down** ramp
(D) Net force zero
(E) Net **constant** force **up** ramp
(F) Net **increasing** force **up** ramp
(G) Net **decreasing** force **up** ramp

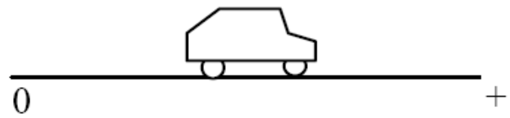
____8. The car is moving up the ramp after it is released.
____9. The car is at its highest point.
____10. The car is moving down the ramp.

Questions 11-13 refer to a coin which is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (**A** through **G**) to indicate the force acting on the coin for each of the cases described below. Answer choice **J** if you think that none is correct. **Ignore any effects of air resistance.**

A. The force is **down** and constant.
B. The force is **down** and increasing
C. The force is **down** and decreasing
D. The force is zero.
E. The force is **up** and constant.
F. The force is **up** and increasing
G. The force is **up** and decreasing

____11. The coin is moving upward after it is released.
____12. The coin is at its highest point.
____13. The coin is moving downward.

Questions 14-21 refer to a toy car which can move to the right or left along a horizontal line (the positive part of the distance axis).



Assume that friction is so small that it can be ignored. A force is applied to the car. Choose the one force graph (A through H) for each statement below which could allow the described motion of the car to continue.

You may use a choice more than once or not at all. If you think that none is correct, answer choice J.

____14. The car moves toward the right (away from the origin) with a steady (constant) velocity.

____15. The car is at rest.

____16. The car moves toward the right and is speeding up at a steady rate (constant acceleration).

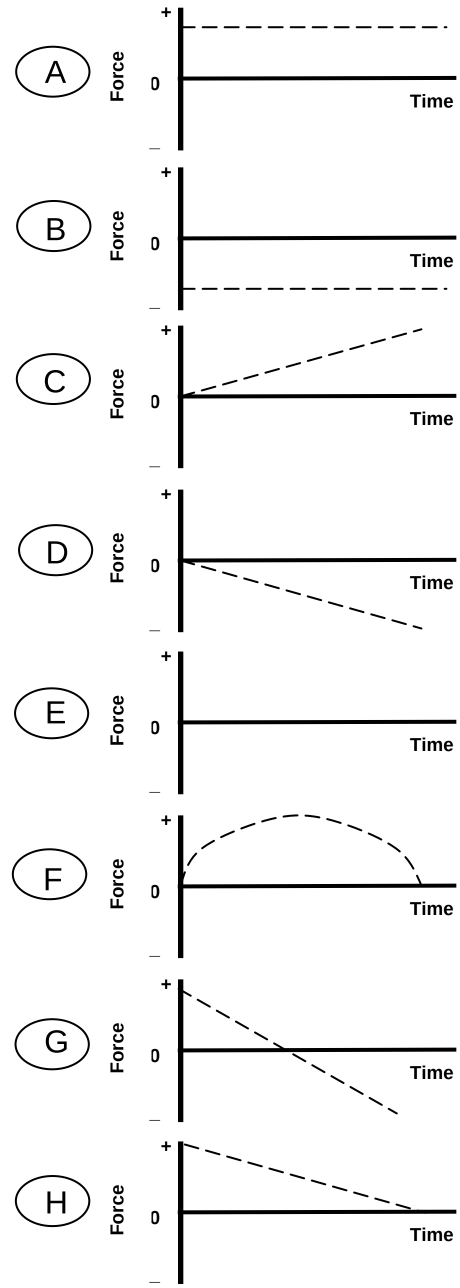
____17. The car moves toward the left (toward the origin) with a steady (constant) velocity.

____18. The car moves toward the right and is slowing down at a steady rate (constant acceleration).

____19. The car moves toward the left and is speeding up at a steady rate (constant acceleration).

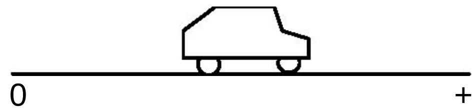
____20. The car moves toward the right, speeds up and then slows down.

____21. The car was pushed toward the right and then released. Which graph describes the force after the car is released.

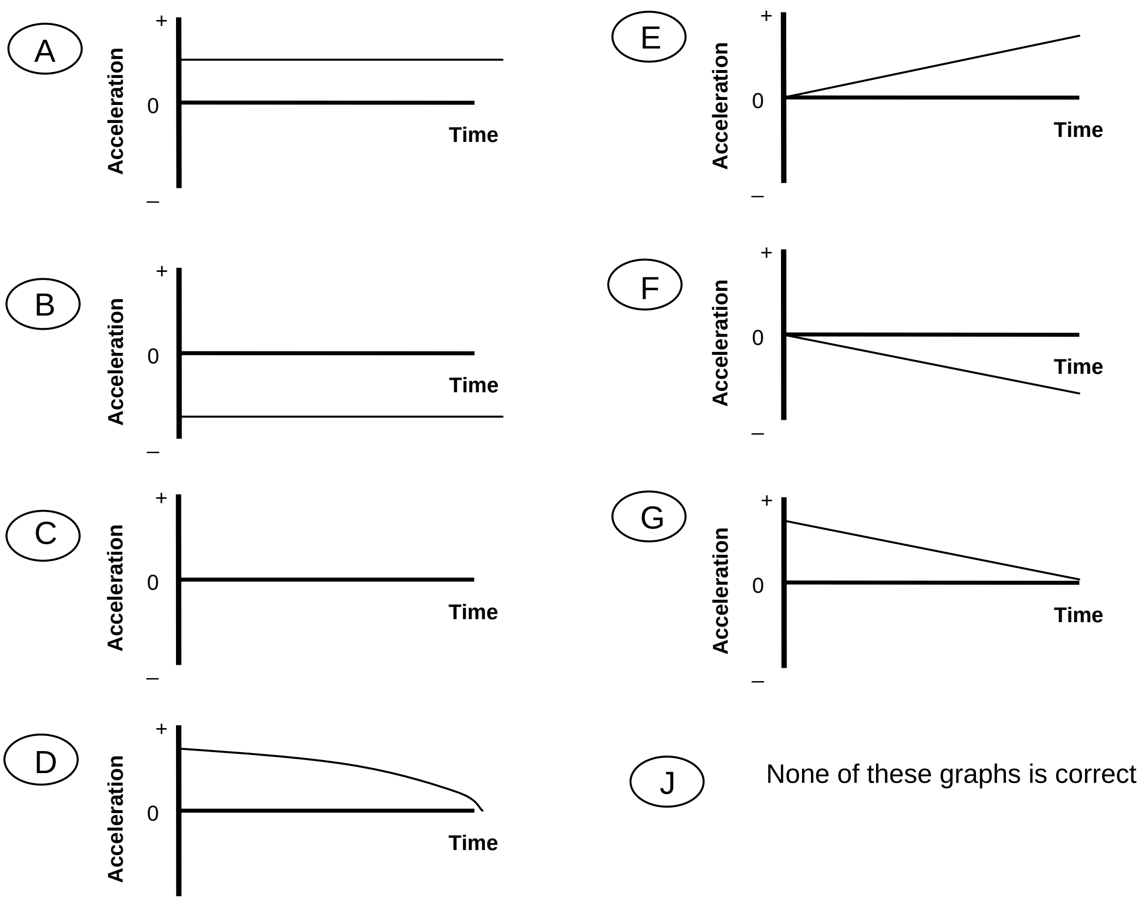


J
None of these graphs is correct

Questions 22-26 refer to a toy car which can move to the right or left on a horizontal surface along a straight line (the + distance axis). The positive direction is to the right.



Different motions of the car are described below. Choose the letter (**A** to **G**) of the **acceleration-time** graph which corresponds to the motion of the car described in each statement.
You may use a choice more than once or not at all. If you think that none is correct, answer choice **J**.



____22. The car moves toward the right (away from the origin), speeding up at a steady rate.

____23. The car moves toward the right, slowing down at a steady rate.

____24. The car moves toward the left (toward the origin) at a constant velocity.

____25. The car moves toward the left, speeding up at a steady rate.

____26. The car moves toward the right at a constant velocity.

Questions 27-29 refer to a coin that is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (**A** through **G**) to indicate the acceleration of the coin during each of the stages of the coin's motion described below. Take **up** to be the **positive** direction. Answer choice **J** if you think that none is correct.

A. The acceleration is in the negative direction and constant.

B. The acceleration is in the negative direction and increasing

C. The acceleration is in the negative direction and decreasing

D. The acceleration is zero.

E. The acceleration is in the positive direction and constant.

F. The acceleration is in the positive direction and increasing

G. The acceleration is in the positive direction and decreasing

____27. The coin is moving upward after it is released.

____28. The coin is at its highest point.

____29. The coin is moving downward.

Questions 30-34 refer to collisions between a car and trucks. For each description of a collision (30-34) below, choose the one answer from the possibilities A though J that best describes the forces between the car and the truck.

A. The truck exerts a greater amount of force on the car than the car exerts on the truck.

B. The car exerts a greater amount of force on the truck than the truck exerts on the car.

C. Neither exerts a force on the other; the car gets smashed simply because it is in the way of the truck.

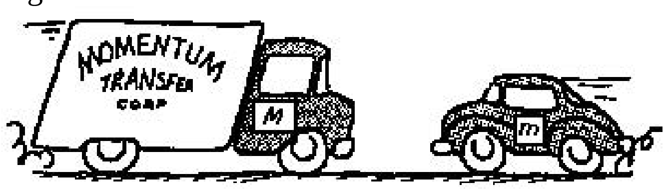
D. The truck exerts a force on the car but the car doesn't exert a force on the truck.

E. The truck exerts the same amount of force on the car as the car exerts on the truck.

F. Not enough information is given to pick one of the answers above.

J. None of the answers above describes the situation correctly.

In questions 30 through 32 the truck is **much heavier** than the car .

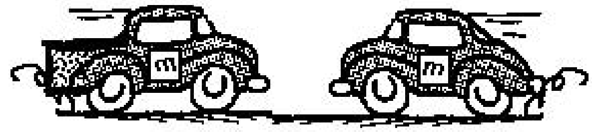


____30. They are both moving at the same speed when they collide. Which choice describes the forces?

____31. The car is moving much faster than the heavier truck when they collide. Which choice describes the forces?

____32. The heavier truck is standing still when the car hits it. Which choice describes the forces?

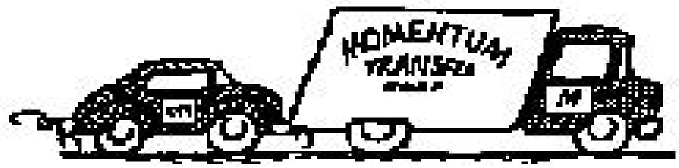
In questions 33 and 34 the truck is a small pickup and is the ***same weight*** *as the car.*



____33. Both the truck and the car are moving at the same speed when they collide. Which choice describes the forces?

____34. The truck is standing still when the car hits it. Which choice describes the forces?

Questions 35-38 refer to a large truck which breaks down out on the road and receives a push back to town by a small



Pick one of the choices **A** through **J** below which correctly describes the forces between the car and the truck for each of the descriptions (35-38).

A. The force of the car pushing against the truck is equal to that of the truck pushing back against the car.

B. The force of the car pushing against the truck is less than that of the truck pushing back against the car.

C. The force of the car pushing against the truck is greater than that of the truck pushing back against the car.

D. The car's engine is running so it applies a force as it pushes against the truck, but the truck's engine isn't running so it can't push back with a force against the car.

E. Neither the car nor the truck exert any force on each other. The truck is pushed forward simply because it is in the way of the car.

F. None of these descriptions is correct.

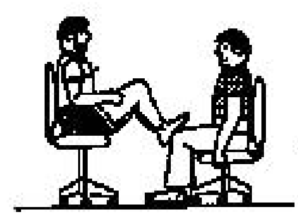
____35. The car is pushing on the truck, but not hard enough to make the truck move.

____36. The car, still pushing the truck, is **speeding up** to get to cruising speed.

____37. The car, still pushing the truck, is at cruising speed and continues to travel at the **same speed**.

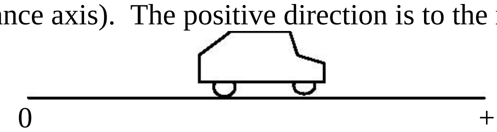
____38. The car, still pushing the truck, is at cruising speed when the truck puts on its brakes and causes the car to **slow down**.

____39. Two students sit in identical office chairs facing each other. Bob has a mass of 95 kg, while Jim has a mass of 77 kg. Bob places his bare feet on Jim's knees, as shown to the right. Bob then suddenly pushes outward with his feet, causing both chairs to move. In this situation, while Bob's feet are in contact with Jim's knees,

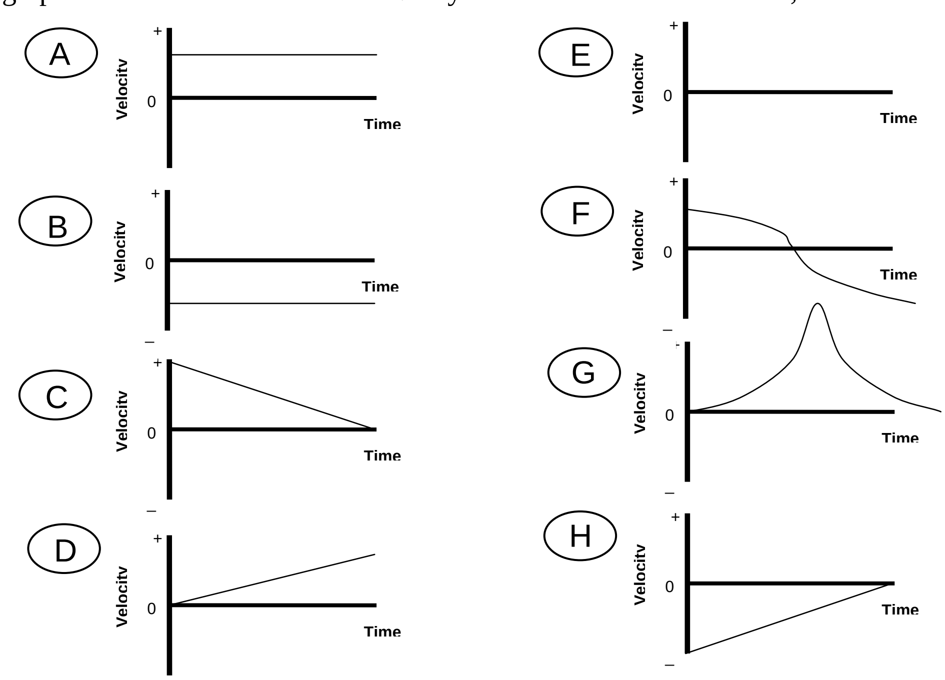


A. Neither student exerts a force on the other. Bob Jim
B. Bob exerts a force on Jim, but Jim doesn't exert any force on Bob.
C. Each student exerts a force on the other, but Jim exerts the larger force.
D. Each student exerts a force on the other, but Bob exerts the larger force.
E. Each student exerts the same amount of force on the other.
F. **J**. None of these answers is correct.

Questions 40-43 refer to a toy car which can move to the right or left along a horizontal line (the positive portion of the distance axis). The positive direction is to the right.



Choose the correct velocity-time graph (A - G) for each of the following questions. You may use a graph more than once or not at all. If you think that none is correct, answer choice J.



J None of these graphs is correct.

____40. Which velocity graph shows the car moving toward the right (away from the origin) at a steady (constant) velocity?

____41. Which velocity graph shows the car reversing direction?

____42. Which velocity graph shows the car moving toward the left (toward the origin) at a steady (constant) velocity?

____43. Which velocity graph shows the car increasing its speed at a steady (constant) rate?

A sled is pulled up to the top of a hill. The sketch above indicates the shape of the hill. At the top of the hill the sled is released from rest and allowed to coast down the hill. At the bottom of the hill the sled has a speed v and a kinetic energy E (the energy due to the sled's motion). Answer the following questions. In every case friction and air resistance are so small they can be ignored.

____44. The sled is pulled up a **steeper** hill of the **same** height as the hill described above. How will the velocity of the sled at the bottom of the hill (after it has slid down) compare to that of the sled at the bottom of the original hill? Choose the best answer below.

A. The speed at the bottom is greater for the steeper hill.
B. The speed at the bottom is the same for both hills.
C. The speed at the bottom is greater for the original hill because the sled travels further.
D. There is not enough information given to say which speed at the bottom is faster.
J. None of these descriptions is correct.

____45. 45. Compare the kinetic energy (energy of motion) of the sled at the bottom for the original hill and the steeper hill in the previous problem. Choose the best answer below.

A. The kinetic energy of the sled at the bottom is greater for the steeper hill.
B. The kinetic energy of the sled at the bottom is the same for both hills.
C. The kinetic energy at the bottom is greater for the original hill.
D. There is not enough information given to say which kinetic energy is greater.
J. None of these descriptions is correct.

____46. 46. The sled is pulled up a higher hill that is less steep than the original hill described before question 44. How does the speed of the sled at the bottom of the hill (after it has slid down) compare to that of the sled at the bottom of the original hill?

A. The speed at the bottom is greater for the higher but less steep hill than for the original.
B. The speed at the bottom is the same for both hills.
C. The speed at the bottom is greater for the original hill.
D. There is not enough information given to say which speed at the bottom is faster.
J. None of these descriptions is correct.

46a. Describe in words your reasoning in reaching your answer to question 46. (**Answer on the answer sheet** and use as much space as you need)

____47. 47. For the higher hill that is less steep, how does the kinetic energy of the sled at the bottom of the hill after it has slid down compare to that of the original hill?

A. The kinetic energy of the sled at the bottom is greater for the higher but less steep hill.
B. The kinetic energy of the sled at the bottom is the same for both hills.
C. The kinetic energy at the bottom is greater for the original hill.
D. There is not enough information given to say which kinetic energy is greater.
J. None of these descriptions is correct.

Appendix C -- The Modified Maryland Physics Expectations Survey

Here are 34 statements which may or may not describe your beliefs about this course. You are asked to rate each statement by checking a number between 1 and 5 where the numbers mean the following:

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

Answer the questions by checking the number that best expresses your feeling. Work quickly. Don't overelaborate the meaning of each statement. They are meant to be taken as straightforward and simple. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, circle 3. If an item combines two statements and you disagree with either one, choose 1 or 2.

		SA	A	N	D	SD
1	All I need to do to understand most of the basic ideas in this workshop is just read the text, work most of the problems, and/or pay close attention in class					
2	All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems					
4	"Problem solving" in physics basically means matching problems with facts or equations and then substituting values to get a number					
5	Learning physics made me change some of my ideas about how the physical world works					
6	When preparing to teach, I read a text in detail and work through many of the examples given there.					
7	In this workshop, I do not expect to understand physics equations in an intuitive sense; they must just be taken as givens					
8	The best way for me to learn physics is by solving many problems rather than by carefully analyzing a few in detail					
9	Physical laws have little relation to what I experience in the real world.					
10	A good understanding of physics is necessary for me to achieve my career goals.					
11	Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation					
12	My learning in this workshop is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it					
13	Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations					
14	In doing a physics problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation					
15	The derivations or proofs of equations has little to do with solving problems or with the skills I need to successfully understand physics					
16	Only very few specially qualified people are capable of really understanding physics					
17	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed					
18	The most crucial thing in solving a physics problem is finding the right equation to use					
19	If I don't remember a particular equation needed for a problem there's nothing much I can do to come up with it					
20	If I came up with two different approaches to a problem and they gave different answers, I would not worry about it; I would just choose the answer that seemed most reasonable. (Assume the answer is not in the back of the book.)					
21	Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I have to do in this workshop					
22	The main skill I get out of this workshop is learning how to solve physics problems.					
23	Learning physics helps me understand situations in my everyday life.					

		S A	A	N	D	S D
24	When I prepare classroom activities, I explicitly think about the concepts that underlie the problem					
25	"Understanding" physics basically means being able to recall something you've read or been shown					
26	Spending a lot of time (half an hour or more) working on a problem is a waste of time. If I don't make progress quickly, I'd be better off asking someone who knows more than I do					
27	A significant problem is helping students to memorize all the information they need to know					
28	The main skill I get out of this workshop is to learn how to reason logically about the physical world					
29	I use the mistakes I make on workshop exercises as clues to what I need to do to understand the material better					
30	To be able to use an equation in a problem (particularly in a problem that I haven't seen before), I need to know more than what each term in the equation represents					

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Maintained by University of Maryland PERG
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Last modified March 2, 2001

The following table details changes made to the MPEX 1, for use with this research.

		Cluster(s)
1	All I need to do to understand most of the basic ideas in this ***workshop*** is just read the text, work most of the problems, and/or pay close attention in class All I need to do to understand most of the basic ideas in this course is just read the text, work most of the problems, and/or pay close attention in class.	Independent
2	All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems	Math
-- **3**	**I go over my class notes carefully to prepare for tests in this course. Question Deleted**	**Effort**
4	"Problem solving" in physics basically means matching problems with facts or equations and then substituting values to get a number	Concepts
5	Learning physics made me change some of my ideas about how the physical world works	
-- **6**	**I spend a lot of time figuring out and understanding at least some of the derivations or proofs given either in class or in the text. Question Deleted**	**Effort**
6 7	When preparing to teach, I read a text in detail and work through many of the examples given there. I read the text in detail and work through many of the examples given there.	Math Effort
7 8	In this ***workshop***, I do not expect to understand ***physics*** equations in an intuitive sense; they must just be taken as givens In this course, I do not expect to understand equations in an intuitive sense; they must just be taken as givens.	Independent Math
8 9	The best way for me to learn physics is by solving many problems rather than by carefully analyzing a few in detail	
9 10	Physical laws have little relation to what I experience in the real world.	Reality
10 11	A good understanding of physics is necessary for me to achieve my career goals. A good understanding of physics is necessary for me to achieve my career goals. ~~A good grade in this course is not enough.~~	
11 12	Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation	Coherence
12 13	My ***learning*** in this workshop is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it.	Independent
13 14	Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations ~~given in class and/or in the textbook~~.	Independent
14	In doing a physics problem, if my calculation gives a result that differs	Coherence

15	significantly from what I expect, I'd have to trust the calculation	
15 16	The derivations or proofs of equations has little to do with solving problems or with the skills I need to ***successfully understand physics*** The derivations or proofs of equations ~~in class or in the text~~ has little to do with solving problems or with the skills I need to succeed in this course.	Coherence Math
16 17	Only very few specially qualified people are capable of really understanding physics	Independent
17 18	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed	Reality
18 19	The most crucial thing in solving a physics problem is finding the right equation to use	Concepts
19 20	If I don't remember a particular equation needed for a problem there's nothing much I can do to come up with it If I don't remember a particular equation needed for a problem ~~in an exam~~ there's nothing much I can do ~~(legally!)~~ to come up with it.	Math
20 21	If I came up with two different approaches to a problem and they gave different answers, I would not worry about it; I would just choose the answer that seemed most reasonable. (Assume the answer is not in the back of the book.)	Coherence
21 22	Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I have to do in this ***workshop*** Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I have to do in this course.	Reality
22 23	The main skill I get out of this ***workshop*** is learning how to solve physics problems. The main skill I get out of this course is learning how to solve physics problems.	
-- **24**	**The results of an exam don't give me any useful guidance to improve my understanding of the course material. All the learning associated with an exam is in the studying I do before it takes place. Question Deleted**	**Effort**
23 25	Learning physics helps me understand situations in my everyday life.	Reality
24 26	***When I prepare classroom activities,*** I explicitly think about the concepts that underlie the problem. When I solve most exam or homework problems, I explicitly think about the concepts that underlie the problem.	Concepts
25 27	"Understanding" physics basically means being able to recall something you've read or been shown	Independent Concepts
26 28	Spending a lot of time (half an hour or more) working on a problem is a waste of time. If I don't make progress quickly, I'd be better off asking someone who knows more than I do	
27 29	A significant problem ***is helping students to*** memorize all the information they need to know A significant problem in this course is being able to memorize all the information I need to know.	Coherence
28 30	The main skill I get out of this ***workshop*** is to learn how to reason logically about the physical world The main skill I get out of this course is to learn how to reason logically about the physical world.	
29	I use the mistakes I make on workshop exercises as clues to what I need	Effort

31	to do to understand the material better I use the mistakes I make on homework and on exam problems as clues to what I need to do to understand the material better.	
30 32	To be able to use an equation in a problem (particularly in a problem that I haven't seen before), I need to know more than what each term in the equation represents	Concepts
-- **33**	**It is possible to pass this course (get a "C" or better) without understanding physics very well. Question Deleted**	
-- **34**	**Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text. Question Deleted**	

Table C-1 – Changes to the MPEX

Table C-1 Notes:

- Where changes were made the revised question is above the line, the original question is below the line. Questions with no dividing line were used in their original form.
- ***Bold Italic*** and ~~strike through~~ indicate minor changes from the original MPEX
- **Bold Book Antiqua font** is used for the five questions deleted from the original MPEX for this workshop survey

The standard MPEX has 34 statements which relate to student beliefs about the physics course they are preparing to take, or have just completed. Students rate each statement by checking one of the following boxes:

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

Students are asked to answer the questions by checking the number that best expresses their feelings. The modifications primarily change ***course*** to ***workshop***, but a few items had more substantial changes. Those are discussed in more detail below, Item numbers are from the standard MPEX.

- Five statements were omitted from the MPEX as used for this workshop, the remaining items were renumbered:
    - Items 3 and 24 referred to student beliefs related to exams, but there were no exams in the workshop.

  - Item 6 referred to students spending a lot of time figuring things out, implying time out of class. The concentrated nature of this workshop did not allow for a lot of time either in or out of the workshop setting.
  - Item 33 refers to expectations for grades in the course, but no grades were given for this workshop.
  - Item 34 refers to a lengthy process of rethinking and restructuring, the concentrated nature of this workshop did not allow for this kind of process.

  Items 3 and 24 are only included in the Effort cluster, which the MPEX developers describe as the least well correlated of the group. Item 6 is included in the Effort cluster as well, but is also included in the Math cluster. The Math cluster contains four other items, so the researchers felt this could be done without significant degradation of the results. Items 33 and 34 are not normally included in the MPEX evaluation, and so have no impact on the results presented.

- Items 7, 26, and 29 were all changed to relate to teacher expectations for how they work in their classrooms, instead of personal use in the class or in life. The focus of the statements did not change, however. These changes should not have a significant impact on MPEX results.
- Item 11 removed a reference to grades in the course without significantly altering the intent of the statement.

- Item 20 also related to exams, but the exam reference was removed without a significant change in the statements intent.
- Item 13 removed changed a reference to “grade in the class” to “learning in the workshop.” The intent of the statement was to show student independent learning, and this change should not affect that intent.
- Item 14 deleted the reference to a source for the knowledge acquired (originally “given in the class and/or in the course text”). This should not alter the intent of the statement
- Item 16 again deleted a reference to source of material (“in class or in the text”), and also changed skills needed to succeed in the course to those needed to successfully understand physics. This shouldn’t alter the intent of the statement.
- The remaining changes merely changed references to the *class* or *course* to references to the *workshop*.

All told the changes should make the MPEX more appropriate to this cohort. There should be no significant changes in the evaluation, with the exception of further degrading the Effort cluster.

Items 5, 9, 11, 23, 28, and 30 are not included in the cluster evaluations.

Appendix D – The Science Teaching Efficacy Belief Instrument

Science Teaching Efficacy Belief Instrument*

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate
letters to the right of each statement.
SA – Strongly Agree A – Agree UN - Uncertain
D – Disagree SD – Strongly Disagree

1	When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	SA	A	UN	D	SD
2	I am continually finding better ways to teach science.	SA	A	UN	D	SD
3	Even when I try very hard, I don't teach science as well as I do most subjects.	SA	A	UN	D	SD
4	When the science grades of students improve, it is most often due to their teacher having found a more effective teaching approach.	SA	A	UN	D	SD
5	I know the steps necessary to teach science concepts effectively.	SA	A	UN	D	SD
6.	I am not very effective in monitoring science experiments.	SA	A	UN	D	SD
7	If students are underachieving in science, it is most likely due to ineffective science teaching.	SA	A	UN	D	SD
8	I generally teach science ineffectively.	SA	A	UN	D	SD
9	The inadequacy of a student's science background can be overcome by good teaching.	SA	A	UN	D	SD
10	The low science achievement of some students cannot generally be blamed on their teachers.	SA	A	UN	D	SD
11	When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.	SA	A	UN	D	SD
12	I understand science concepts well enough to be effective in teaching elementary science.	SA	A	UN	D	SD
13	Increased effort in science teaching produces little change in some students' science achievement.	SA	A	UN	D	SD
14	The teacher is generally responsible for the achievement of students in science.	SA	A	UN	D	SD
15	Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	SA	A	UN	D	SD
16	If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.	SA	A	UN	D	SD
17	I find it difficult to explain to students why science experiments work.	SA	A	UN	D	SD
18	I am typically able to answer students' science questions.	SA	A	UN	D	SD
19	I wonder if I have the necessary skills to teach science.	SA	A	UN	D	SD
20	Effectiveness in science teaching has little influence on the achievement of students with low motivation.	SA	A	UN	D	SD
21	Given a choice, I would not invite the principal to evaluate my science teaching.	SA	A	UN	D	SD
22	When a student has difficulty understanding a science concept, I am usually at a loss as to how to help the student understand it better.	SA	A	UN	D	SD
23	When teaching science, I usually welcome student questions.	SA	A	UN	D	SD
24	I don't know what to do to turn students on to science.	SA	A	UN	D	SD
25	Even teachers with good science teaching abilities cannot help some kids learn science.	SA	A	UN	D	SD

The STEBI is divided into two constructs, the Personal Science Teaching Efficacy (PSTE) scale and the Science Teaching Outcomes and Expectancies (STOE) scale. The PSTE includes 13 questions: 2, 3, 5, 6, 8, 12, 17-19, and 21-24. These questions deal with the teachers beliefs about their own science teaching abilities. The STOE includes 12 questions: 1, 4, 7, 9-11, 13-16, 20, and 25. These questions deal with the teachers beliefs about the effectiveness of science teaching in general, and whether good teaching has positive impacts on students.

Appendix E – Workshop Schedule

Day - Item	Description	Equipment	Location/***Curriculum Activity***	Time	Cum Time
1-1	Introduction/Housekeeping	None		0.5	0.5
1-2	FMCE/MPEX Diagnostics	None		1.0	1.5
1-3	Physics 500	Stopwatches, Wind Up Cars, Balls, etc	Page A1-A6 ***Activity 0.1.3***	0.5	2.0
1-4	Why Teach Physics in Elementary School – Maine Learning Results	None	Maine Learning Results	0.5	2.5
1-5	Workshop Pedagogy & Expectations	None		0.5	3.0
1-6	EIP – The Measurement Process ➢ First Look At Motion ➢ Describing and Classifying Motion	 Skate Board, Rolling Chairs, Etc Cars, balls, books, variety of moving objects	Page A7-A10 ***Activity 1.1.1 and 1.1.2***	0.5 0.5	3.5 4.0
1-7	Lunch – Continue with Describing and Classifying motions, Start Defining Speed, What is Speed, Describing Motion -- Reflection	Stop Watches, rulers, meter sticks, tape measures, balls, cars	Page A10 – A12D ***Activity 1.1.3, 1.1.4. and Activity 1.1.5***	1.0	5.0
1-8	Uniform Motion – Ball on flat track ➢ Collect Data ➢ Develop Position/Time Graph ➢ Discuss Position/Displacement ➢ Discuss Time/Duration/Instant	Flat Tracks, ball bearings, stopwatches, ramps, Graph Paper	Page A12E – A12K ***Activity 1.1.6***	2.5	7.5
1-9	How does this apply: To teachers: To Students	None		0.5	8.0

Day - Item	Description	Equipment	Location/***Activity***	Time	Cum Time
2-1	Introduce Days Activities, Discuss Pedagogy and Epistemology	None	None	0.5	0.5
2-2	Complete Uniform Motion Experiment and Outbriefs	None	***Activity 1.1.6***.	2.0	3.0
2-3	Exercises in Uniform Motion, Position Time Graphs, Predicting Motion and Position,	Graph Paper, Making Connections Test from IIPS	Page A12C – A12D ***Uniform Motion Exercises***	1.0	4.0
	Lunch — Reflection			0.5	4.5
2-4	Intro to Velocity	None	Page A17 – A21 ***Activity 2.2, 2.2.1, and 2.2.2***	1.0	5.5
2-5	Analyzing Motions – Trying Out the Motion Sensors	Motion Sensors, Graph Paper, Computers, Cards	Page A13 – A16 ***Activity 2.1.1 and 2.1.2***	1.0	6.5
2-6	Matching Game	Same	Page A17A – A17B ***Activity 2.1.3***	1.5	8.0
2-7	What did you learn, how does it apply?	None		0.5	8.5

Day - Item	Description	Equipment	Source	Time	Cum Time
3-1	Intro, Pedagogy, Epistemology	None		0.5	0.5
3-2	Position and Velocity Graphs	Motion Sensors, Graph Paper, Computers, Carts and tracks	Page A21 – A24 ***Activity 2.2.3***,	2.0	2.5
3-3	Effect of a Push	Motion Sensors, Graph Paper, Computers, Carts and tracks	Page A25 – A29 ***Activity 2.3, 2.3.1, 2.3.2***	1.0	3.5
	Lunch			0.5	4.0
3-4	Motion from Constant Force	Big Rubber Bands, bungee cords, skate board – low friction cart, Fan carts, clamp and post, PVC pipe, motion sensor	Page A31 – A38 ***Activity 3, 3.1, 3.1.1, 3.1.2, 3.1.3***	2.0	6.0
3-5	Acceleration – Slope of velocity/time graph, sign of acceleration, Position/Velocity/Acceleration graphs	None	Page A39 – A46 ***Activity 3.2, 3.2.1, 3.2.2, 3.2.3***	2.0	8.0
3-6	What did you learn, how does this apply?	None	None	0.5	8.5

Day - Item	Description	Equipment	Source	Time	Cum Time
4-1	Intro, Pedagogy, Epistemology	None	None	0.5	0.5
4-2	IIPS Making Connections, Accelerated Motion	None	Page A46C – A 46E ***Activity 3.2.5***	1.0	1.5
4-3	Force and Motion Cart on inclined ramp – force down ramp Causing a Car to Accelerate (easier to push a car or truck?)	Dynamic cart and track, Motion Sensor, spring scale or force sensor	Page A47 – A50 ***Activity 3.3, 3.3.1, 3.3.2***	1.0	2.5
4-4	Mass and Acceleration – Does more stuff change the slope? .	Dynamic Carts and tracks, motion sensors, spring scale or force sensor, Computer with Printer	Page A51 – A56 ***Activity 3.3.3, 3.3.4, 3.3.5, 3.3.6***	1.0	3.5
	Lunch				
4-5	Gravity as a Force – Tossed Ball, Dropped (Bouncing) Ball, Free Body Diagram of Tossed Ball	Balls, Basketball, motion sensor, small similar size, different mass objects to drop –	Page A57 – A 61 ***Activity 4.1, 4.1.1, 4.1.2***	1.0	4.5
4-6	Multiple Forces – Fan Carts up and down an incline, multiple fans on same cart	Fan Carts, tracks, motion sensor, spring scale or force sensor	Page A65 – A69 ***Activity 4.2, 4.2.1, 4.2.2, 4.2.3***	1.5	6.0
4-7	Making Connections: Inertia & Newton's 1st Law - Free Body Diagrams	None	IIPS Making Connections and 2.2.1 ***Newton's First Law Exercises,***	1.5	7.5
4-8	Talking Science - What did you learn? How does it apply?	None	None	0.5	8.5

Day - Item	Description	Equipment	Source	Time	Cum Time
5-1	Intro, Pedagogy, Epistemology	None	None	0.5	0.5
5-2	Impulse and Momentum – Explorations with things that collide.	Balls, tracks, carts, etc.	***Activity 4.3.1***	2.0	2.5
5-3	Momentum – Developing a feel for momentum	None	Univ of Md, Dealing with … Newton's 3rd ***Activity 4.3.1***	1.5	4.0
	Lunch – Reflection			0.5	4.5
5-4	Making Connections, Newton's 2nd Law	None	IIPS Making Connections ***Newton's 2nd Exercises***	1.0	5.5
5-6	Duration of a Force, Conservation of Momentum	Reading on Impulse and Momentum, Newton's Cradle	IIPS Dynamics, Pg 8-12, 2.5.2 ***Activity 4.3.2***	0.5	6.0
5-7	Talking Science, what did you learn? How does it fit?	None	None	0.5	6.5
5-8	Post-tests	FMCE, MPEX/STEBI	None	1.0	7.5
5-9	Wrap up, interview volunteers, hand out checks	None	None	1.0	8.5

Appendix F - Participant Interviews

General Comments

Interviews were conducted about three weeks after the workshops with volunteer participants. The Interviews were intended to determine participant attitudes towards the completed workshop, to look for improvements to the workshop format, and to evaluate participant retention of the material covered in the workshop. Following the interview, most of the participants spent some time asking questions about the physics covered in the workshop and clarifying some of the points they found difficult.

Eleven workshop participants also took part in the interviews. The interviews were videotaped, however technical difficulties with the first interview made that tape unusable. Five of the interviewees were from the Sidney workshop, and six were from the Presque Isle workshop. Two men and nine women were interviewed, FMCE scores ranged from the bottom to the top of the group. Age and experience ranged from young teachers with a few years experience to veteran teachers with 20-30 years experience.

Interview Protocol

The following general protocol was used; follow up questions were pursued where they seemed pertinent.

- Did you find the workshop useful?
- Can you think of any ways to improve the workshop?

- Was the group work effective?
- Was the pace of the workshop appropriate?
- Was the instruction/facilitation adequate?

The following discussion points were based on questions 8,9,10 and 35, 36, 37, and 38 from the FMCE. Interviewees were provided a copy of the FMCE to better illustrate the questions, and Presque Isle participants were provided a ball and ramp to simulate the car-on-ramp motion.

- Given a small car on a sloping ramp, the car is given a quick push up the ramp by a hand. Describe the motion of the car from the time it leaves the hand until it returns to the location of the push in terms of velocity. Draw a velocity/time graph for the motion.
- Describe the same event in terms of acceleration. Draw an acceleration/time graph for the motion.
- Describe the same event in terms of force applied. Draw a force/time graph for the motion.
- Given a book on a table, describe the forces acting on the book.
- A large truck breaks down on the highway. A driver with a small car happens onto the situation, and volunteers to push the truck into town.
    - When the car is pushing on the truck, but not hard enough to make the truck move, is the force of the car on the truck more than, less than, or equal to the force of the truck on the car?

- The car is still pushing, but now both the truck and car are accelerating to highway speed. The truck and car maintain contact during this time. Is the force of the car on the truck more than, less than, or equal to the force of the truck on the car?
- The car and truck reach highway speed and proceed at a constant speed along the highway. The car and truck maintain contact during this time. Is the force of the car on the truck more than, less than, or equal to the force of the truck on the car?
- The truck driver sees a stop sign ahead, and steps on the brakes to prevent the truck from going out into the cross traffic. While the truck slows down the car continues to push, and the truck and car maintain contact. Is the force of the car on the truck more than, less than, or equal to the force of the truck on the car?

In general the interviews showed that the workshop may have been too ambitious. Many participants complained that there was too much information presented too quickly, and that they didn't have time to fully absorb the material before moving on to the next topic. Generally they found the pace a little quick, but most didn't want it slowed very much. They found the group work not only effective, but essential to the learning process, and the facilitation adequate. Many commented that they liked having a learning facilitation process modeled for them, and felt they might try to give their students more time to learn on their own before "giving" the answer. Others complained that they would have liked more direct guidance.

The content questions generally revealed the participants had retained the material they had learned in the workshop, although one participant demonstrated a slight deterioration in velocity knowledge and another demonstrated a deterioration of Newton's 3rd resources. There were two cases where participants showed force resources that the FMCE, didn't record, and a third who demonstrated better acceleration resources than the FMCE predicted. Individual interview summaries follow, participant ID numbers are provided to allow comparison with other diagnostics. FMCE summaries are given in the following format: V(velocity), pretest – post-test; A(acceleration), pre – post; F 1&2, pre-post; F3, pre – post; O(overall), pre – post, pre and post-test scores in percent.

Participant #17

- Provide more explanations and background material.
- Letting students work through problems might be better for them in the long run, might provide better learning.
- Group work was effective.

- The pace was good, letting groups work at their own speed was very good.
- Fitting this kind of learning into elementary classrooms would be difficult. There are too many other demands on time and interruptions to schedules.

Car on Ramp

- Velocity – Increase on way up, stop at top, then slide back down. Velocity graph – 1st try - up sloping line to peak, then sloping back to zero. 2nd try, fastest at beginning, then slows down and comes to stop. New line from positive y-axis sloping to right down to zero, then back towards 0 time. 3rd try, erased line sloping back to left, and extended line (correctly) through zero velocity and on to right in negative velocity.
- Acceleration – Gets less as it goes up, then accelerates going down. Acceleration is distance/time … velocity is change in acceleration.
- Force – From hand and gravity. After it leaves the hand force from movement of car and gravity.

Book on Table

- Forces are gravity and no others

Car and Truck

- Forces the same for both car and truck in all four situations.

<u>FMCE</u>: V, 50 – 100; A, 17 – 0; F 1&2, 6 – 0; F3, 50 – 100; O, 21 – 30

No significant change from post-test results

Participant # 25

- Workshop was useful, not so much for the physics but for the teaching techniques … how do you teach something difficult … the procedures that could be used, the hands-on work, the repetition.
- The workshop was pretty intense for five straight days. Would have been better spread over a longer time, maybe one day a week for five weeks? But teachers wouldn't go for that kind of time commitment.
- Liked the hands-on work
- Pace a little fast … but reasonable for time available and material covered
- Group work was good, sometimes one person in group would get material and help others, other times it would be a different person.
- Facilitation was OK … but frustrating at times to not get answers. Would be good to have given a little more information when people get frustrated.

Car on Ramp

- Velocity – Velocity is speed with direction. The force from the hand … as soon as the hand goes away the force is down, but the car continues to move up. Velocity graph – sloping up for constant, then curve for slowing down. After slight prompting drew a correct graph.

- Acceleration – Most confusing part of workshop. Acceleration is rise over run. Plot points, divide velocity by time. Very confused.
- Force – Mass x acceleration. Forces applied, mass of car and gravity. Acceleration has to change because the car stops.

Book on Table

- Forces, gravity pulling it down, table holding it up.

Car and Truck

- I remember that forces are the same for all cases. But it seems like truck would have more force, or something hitting another would have more force … but it doesn't.
    - Truck stopped – forces the same on both … until truck starts moving
    - Accelerating – more force from car
    - Constant Speed – forces the same
    - Truck slowing down – more force from truck

FMCE: V, 100 – 100; A, 0 – 17; F 1&2, 6 – 38; F3, 17 – 100; O, 18 – 51

No significant change from post-test … one of the highest scoring participants

Participant # 9

- The workshop was useful for enhancing background, but not for use in elementary school classroom.

- Needed more time, spread workshop over two weeks and narrow the focus
- Pace was OK, groups were given enough time to work through issues
- Group work was effective – Use your own brain, then share a brain concept used in elementary school.
- Extra facilitator in Augusta was necessary … more facilitators might have been even better.
- Frustrating at times, to much knowledge in work.

Car on Ramp

- Velocity – Start up ramp, get to (top) point and stop, then come back down. Velocity is speed with direction. Velocity graph (couldn't see in video) – some problems with graph, couldn't produce correct graph even with prompting. Understood velocity was greatest after push and at same point on return.
- Acceleration – Decreasing up, increasing down. "Actually when we threw the ball up everything stayed the same (tossed ball, constant acceleration). Had difficulty pulling acceleration together, but had good grasp on velocity.
- Force – Gravity is only force. Couldn't produce force/time graph.

Book on Table

- `Gravity down, table up. The book isn't moving.

Car and Truck – Force the same from both car and truck in all four situations.

<u>FMCE:</u> V, 0 – 100; A, 0 – 17; F 1&2, 0 – 31; F3, 17 – 67; O, 3 – 42

Resources seemed comparable to post-test results, maybe a slight regression

<u>Participant #44</u>

- Found things she was not teaching correctly (in her classroom)
- Answer questions more directly, especially for simple errors.
- More study time – limited available summer time for teachers is a problem.
- Group members helped each other, commiserated when things didn't work.
- Liked working through experiments, they helped her understand the situations.

Car on Ramp

- Velocity – Increased by hand, would continue if not on ramp, but ramp slows it down, brings it to a stop, then it accelerates down again. Velocity graph – initially drew a graph with two upward sloping segments of different slope, and indicated that the first showed where the hand was in contact. Second slope was flatter. Reached peak, then changed to downward sloping line back to time axis. Couldn't produce correct graph even with prompting.

- Acceleration – Acceleration is an increase in speed. The car accelerates down the ramp. Acceleration graph showed an upward sloping line starting at the origin.
- Force – No forces after the car leaves the hand. Slows down because of the incline, force of incline or gravity. Seemed to be confusing force and velocity. Described the force graph as showing the slowdown.

Book on Table

- Air and mass pushing down, table pushing up. The two forces are equal, so the book maintains its position.

Car and Truck

- Truck Stopped – Equal forces
- Accelerating – Car force greater than truck … it's pushing the truck!
- Constant Speed – Car and truck both less force and equal
- Slowing down – Truck force greater than car

<u>FMCE:</u> V, 100 – 100; A, 0 – 0; F 1&2, 6 – 13; F3, 17 – 0; O, 18 – 18

Seems like a slight deterioration in velocity resources, rest seems comparable to post-test

<u>Participant #42</u>

- Hands-on work was good, computers were neat, both could be done with fourth graders.

- Don’t switch groups
- A lot of information in a short time
- Didn’t lecture
- Participants doing stuff all of the time
- Had to start thinking right away
- Pace was OK, but covered a lot of stuff … a rigorous course. Not overwhelmed, but could slow down just a hair. Any faster would have led t o rebellion.
- Group work was good. Would have been lost if no group, groups provided ideas.
- Good instruction … liked facilitation.

Car on Ramp

- Velocity – car accelerates, stops, returns in other direction … accelerates opposite. All constant velocity … constant acceleration. Velocity graph – first produced a graph with a line sloping from origin upward to right to peak, then downward to right back to time axis. Eventually produced a correct graph after prompting.
- Acceleration – no clear description from acceleration perspective.
- Force – gravity … weak discussion.
- Confused force, velocity, and acceleration.

Book on Table

- Gravity … no other force. Table up equals gravity down.

Car and Truck

- Truck stopped – both forces equal
- Accelerating – car force greater than truck force.
- Constant velocity – Equal forces … can't be but … (showed some confusion)
- Slowing down – truck force greater than car force
- Came to Newtonian perspective with prompting

<u>FMCE:</u> V, 75 – 50; A, 17 – 17; F 1&2, 6 – 31; F3, 0 – 0; O, 15 – 24

Demonstrated weak resources, probably no significant change from post-test

<u>Participant #37</u>

- Workshop useful, not so much that they will teach to this level, but good background.
- Beneficial – a lot of information in a short time, sometimes confusing material day to day … similar material on subsequent days made things difficult. A longer course might be better … maybe once a week.
- Pace was rigorous
- Groups were good

- Instruction was frustrating because of no (straight) answer policy. But it was effective (because they had to work through it themselves).

Car on Ramp

- Velocity – velocity decreases to stop, increases down (said acceleration while clearly describing velocity). Produced correct velocity graph with no prompting.
- Acceleration – Constantly decreasing till turn around, then increasing. Acceleration graph – drew a positive horizontal line, step straight down to negative side of graph, then horizontal negative line.
- Force – Force of ramp … very weak discussion

Book on Table

- Gravity (down) and table pushing up. Balanced forces, the book is not moving.

Car and Truck

- Equal forces on both car and truck for all four cases.

<u>FMCE:</u> V, 50 - 75; A, 0 – 17; F 1&2, 0 – 13; F3, 17 – 100; O, 9 - 36

No significant changes from post-test

<u>Participant #41</u>

- Workshop was useful, some things that could be used in class

- A lot of information, maybe a little slower would be better … but it would be hard to get teachers to take a two week workshop.
- The pace was OK
- Groups were effective
- Liked having to work stuff out

Car on Ramp

- Velocity – velocity slowly decreases, stops, then increases in negative direction. Drew correct velocity graph with no prompting. Change in distance with time.
- Acceleration – Confusion between velocity and acceleration
- Force – Always down ramp, same magnitude. Drew correct force graph with no prompting. Constant force means constant acceleration.

Book on Table

- Force down (gravity) and up (table). Balanced forces, the book is not moving.

Car and Truck

- Not moving – Same forces on both car and truck
- Accelerating – car force greater than truck force
- Constant velocity – car force greater than truck force, it's pushing the truck

- Slowing down – truck force greater than car force

FMCE: V, 50 – 100; A, 0 – 0; F 1&2, 0 - 0; F3, 0 – 17; O, 6 - 15

Demonstrated good velocity resources in interview. Demonstrated better F 1&2 resources than indicated on FMCE.

Participant #39

- Workshop was useful … it clarified misconceptions. Neat to see how things worked out.
- Group work was helpful. Previous knowledge would have been useful, or more guidance from instructor. Lack of enthusiasm when frustrated.
- Pace was good. Had time to understand before moving on.
- Explanations after-the-fact were beautiful, but frustrating in process. Maybe throw in a bone once in a while.

Car on Ramp

- Velocity – slowdown, stop, reverse direction, increase. Confusion with terms. Velocity graph – drew a lot of different graphs before eventually coming up with correct one with some prompting.
- Acceleration – couldn't remember
- Force – force from hand and force from gravity are equal.

Book on Table

- Push and pull force … gravity pulling, table pushing up – forces are equal, the book is not moving.

Car and Truck

- Forces are equal for both car and truck in all four cases.

<u>FMCE:</u> V, 50 – 100; A, 0 – 33; F 1&2, 0 – 0; F3, 0 – 67; O, 6 - 30

No significant changes from end of workshop to interview.

<u>Participant #45</u>

- Workshop was useful – need lots of review to get it all straight.
- A lot of material in a short time – more spread out would be better for learning … but it would be hard to get teachers to spend more time.
- Pace should be slower to get things straight … needed time to “internalize”
- Group work was good
- Facilitation was good … liked having to do work, saw good facilitation modeled.

Car on Ramp

- Velocity – slowly decreasing, stop, increase on way down. Drew line starting on positive velocity axis, sloping downward to right to time axis, then back upwards sloping up and right.

- Acceleration – Negative acceleration going up the ramp, and positive going down. Decreased in speed going up, increased in speed going down. Acceleration is increase or decrease in speed. Drew a nice velocity graph in place of the acceleration graph.
- Force – talked through confusion on force, arriving at gravity as the only applied force, and gravity being constant. Drew correct force graph, no prompting for either graph or discussion.
- When asked about the relationship between force and acceleration, correctly identified increased force means increased acceleration, then applied that idea to redraw acceleration graph correctly when asked.

Book on Table

- Gravity down, table up. Book isn't moving, so forces are equal.

Car and Truck

- Not Moving – truck force greater than car force
- Accelerating – car force greater than truck force
- Constant Velocity – force of car and truck equal
- Slowing – truck force greater than car force

<u>FMCE:</u> V, 75 – 50; A, 0 – 0; F 1&2, 0 – 13; F3, 0 - 17; O, 9 - 15

Seemed to present better acceleration and velocity resources in interview than shown on FMCE. Still confusion between terms.

<u>Participant #4</u>

- Workshop was useful, “made me think about motion and force and how I might present them to kids.”
- Improve workshop by finding illustrations in everyday life to relate or demonstrate points. “disharmony I couldn’t get beyond because it was presented so quickly” … needed more time.
- Less material covered more deeply would be better
- Group work was useful
- Facilitation was adequate, but took to long to get answers, so understanding wasn’t firm.

Car on Ramp

- Decreasing force up ramp, zero force at top, increasing force down ramp
- Velocity – velocity greatest at release, slows to stop at top, then increases down ramp. Drew correct velocity graph with no prompts.
- Acceleration – Defined acceleration correctly, looked at straight (sloping) velocity graph and said acceleration was constant. Drew correct acceleration graph … but noted confusion.
- Force – gravity pulling down in both directions, confused but almost puts together that force is constant.

Book on Table

- Book is pushing down and table is pushing up. Forces are equal because the book isn't moving.

Car and Truck

- Stopped – Car force greater than truck force
- Accelerating – Car and truck forces are equal
- Constant Velocity – Car force less than truck force
- Slowing – Car force less than truck force.

<u>FMCE:</u> V, 25 - 75; A, 0 - 67; F 1&2, 0 - 50; F3, 0 - 100; O, 3 - 63

Force, velocity and acceleration resources demonstrated in interview seem comparable to post-test results, F3 results are lower than post-test … some material seems to be slipping away.

Appendix G – FMCE Analysis

The FMCE was scored using a template developed by Michael Wittmann at the University of Maryland using a rubric he received from Robert Thornton. The rubric uses 36 of the 47 questions for an overall score, omitting questions that serve to “prime” the response to others, and also omitting the responses to the four energy questions at the end of the evaluation. In three places it groups a set of three questions and gives a score of 2 if all three are correct, and zero if not. The maximum total overall score is 33. The rubric and template also break the scores down into five clusters, representing content knowledge in Velocity, Acceleration, Force 1&2 (Newton’s first and second laws), Force 3 (Newton’s third law), and Energy. Normalized Gains (g) as used here are calculated as:

$$\frac{\text{(Post-test \% - Pretest \%)}}{\text{(100 - Pretest \%)}}$$

Where this resulted in negative gains the Normalized Gain was calculated as percent of possible loss:

$$\frac{\text{(Post-test \% - Pretest \%)}}{\text{Pretest \%}}$$

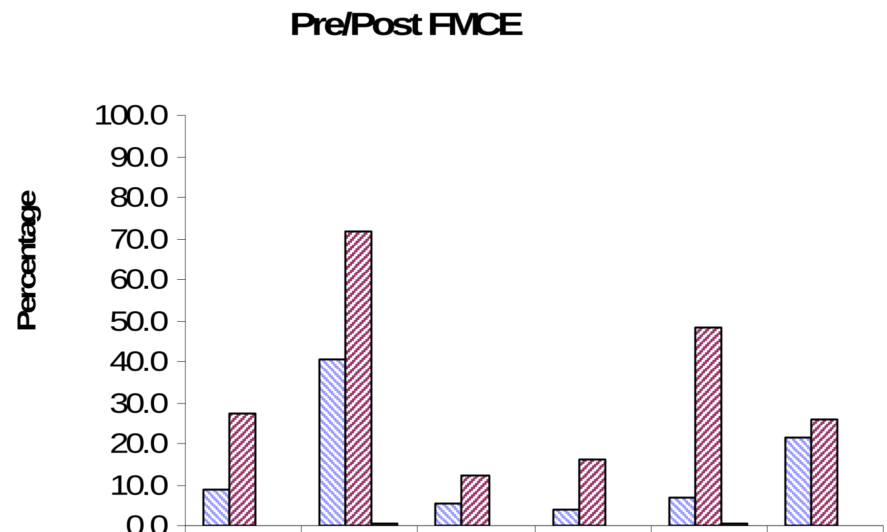
The results were found to be statistically significant using a paired t-test to evaluate the means of the pre- and post-tests. The results are shown in Table G-1.

The pre- and post-test FMCE results for the entire group are shown in Figure G-1. The results for the Overall and Cluster scores are given in percent of possible score. The FMCE was scored in the same manner on an individual basis, with the results shown in Tables G-3 and G-4 at the end of

t-Test: Paired Two Sample for Means		
	Pretest	Post-Test
Mean	9.0	27.5
Variance	37.0	158.0
Observations	29	29
Pearson Correlation	-0.04257	
Hypothesized Mean Difference	0	
df	28	
t Stat	-7.01	
P(T<=t) one-tail	6.25E-08	
t Critical one-tail	1.70	
P(T<=t) two-tail	1.25E-07	
t Critical two-tail	2.05	

Table G-1 – FMCE t-test Results

this appendix. These results were used to determine if there were any significant variations in different groupings of the participants. The results of correlation tests between the post-test FMCE clusters and the overall pre-and post-test scores are shown in Table G-2 below. There is a strong correlation between post-test score and normalized gain, but that is not surprising given the uniformly low pretest scores of this group. Nearly everyone improved from pretest to post-test, and some of the improvements were large. Normally the material covered in this workshop is learned sequentially, with acceleration building on velocity knowledge, and understanding of force building on understanding of acceleration. As a result, those who do well on acceleration and force questions usually do well on velocity questions and also score well on the overall test. That trend can be seen here as well, however the correlation between the velocity results and those for acceleration and force are somewhat suspect.



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	9.0	40.5	5.2	3.9	6.9	21.6
Post-%	27.5	71.6	12.1	16.2	48.3	25.9
Norm Gain (g)	0.20	0.52	0.07	0.13	0.44	0.05

Figure G-1 – FMCE Pre/Post Results

The results for the group on the velocity cluster were fairly strong, but those in the acceleration cluster were very poor. On the post-test only five of the participants correctly answered more than one of the six questions used to score the cluster, and over half did not answer any of them correctly. Still, that was an improvement over the pretest, where 21 of 29 answered all of the acceleration questions incorrectly. Although the acceleration score correlations seem to be significant statistically, and seem to follow expected trends, they should be viewed with some caution due to the very low scores recorded.

	FMCE post	*Norm Gain*	*Velocity*	*Accel*	*F1,2*	*F3*	*Energy*	*FMCE Pre*
FMCE post	1.00							
St Gain	0.93	1.00						
Velocity	0.31	0.23	1.00					
Acceleration	0.69	0.68	-0.10	1.00				
F1,2	0.69	0.64	-0.15	0.49	1.00			
F3	0.73	0.70	0.28	0.42	0.12	1.00		
Energy	0.26	0.17	0.03	0.41	0.05	0.26	1.00	
FMCE Pre	-0.04	-0.41	0.15	-0.19	-0.03	-0.05	0.16	1.00

Table G-2 – FMCE Pre/Post-test and Cluster Correlations

The pretest scores are low compared to other research using this diagnostic[p,q,r,s]. However, most of the data available comes from studies in calculus based courses with students in engineering and science programs. We did not find any FMCE study data from in-service elementary teacher cohorts. However Pollock's[3] work includes discussion of a subgroup of students who were more heavily weighted towards women and non-declared majors, and is probably closer in makeup to the in-service teacher group discussed here. This group also had lower pretest and post-test scores, and gains. Our results are lower than Pollock's, but are more consistent with that

[p] C. Hoellwarth, M. Moelter, and R. Knight, "*A direct comparison of conceptual learning and problem solving ability in traditional and studio style classrooms"*, American Journal of Physics. 73 (5) 459-462, May 2005

[q] K. Cummings, J. Marx, R. Thornton and D. Kuhl, *"Evaluating innovation in studio physics", Physics Education Research*", American. Journal of Physics Supplement 67 (7), July 1999

[r] S. Pollock, *"No Single Cause: Learning Gains, Student Attitudes, and the Impacts of Multiple Effective Reforms"*, CP 790, 2004 Physics Education Research Conference, American Institute of Physics

[s] M. Wittmann, C. van Breen, "*Interim Report for the Real Time Physics and Interactive Lecture Demonstration Dissemination Project"*, Nov. 2000 FIPSE meeting.

group. The average gain is consistent with gains seen by university physics students after a semester of traditional instruction. The normalized gains on the Velocity and Force (3) clusters are much higher than the rest of the diagnostic. The average Velocity score for the post-test was over 70%, and 17 of the 29 participants scored 75% or more in this area. The average score on the Force (3) cluster was 48%, and 14 of the 29 participants scored at or above 67%; this showing is not quite as strong as the Velocity result, but still strong given the short time spent in this area. We used a "refining intuitions" worksheet developed by the University of Maryland with the Newton's 3rd Law material.[t] Other research at the University of Maine indicates that this worksheet is a powerful way to present this material.[u] This proved true in our research as well.

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[t] Elby, A. (2001). "Helping physics students learn how to learn", *American Journal of Physics, Physics Education Research Supplement, 69*(7), S54-S64. http://www2.physics.umd.edu/~elby/papers/epist1/epist_curric.htm.

[u] T. I. Smith and M. C. Wittmann, "Three methods of teaching Newton's Third Law," Physical Review Special Topics - Physics Education Research submitted (2006).

	Overall Score			Velocity Cluster			Acceleration Cluster		
ID	**Pretest**	**Post-Test**	**Norm Gain**	**Pretest**	**Post-Test**	**Norm Gain**	**Pretest**	**Post-Test**	**Norm Gain**
4	3	64	0.63	25	75	0.67	0	67	0.67
9	3	42	0.41	0	100	1.00	0	17	0.17
10	0	18	0.18	0	50	0.50	0	0	0.00
11	15	33	0.21	75	100	1.00	17	0	-1.00
12	3	18	0.16	0	100	1.00	17	0	-1.00
14	9	30	0.23	25	25	0.00	0	17	0.17
15	12	24	0.14	100	100	1.00	0	0	0.00
16	21	30	0.12	50	50	0.00	33	33	0.00
17	21	30	0.12	50	100	1.00	17	0	-0.20
18	15	21	0.07	75	100	1.00	0	0	0.00
20	3	27	0.25	25	100	1.00	0	0	0.00
21	6	36	0.32	0	75	0.75	0	17	0.17
23	9	27	0.20	25	75	0.67	0	0	0.00
24	9	15	0.07	25	0	-1.00	0	0	0.00
25	18	52	0.41	100	100	1.00	0	17	0.17
32	3	12	0.09	0	25	0.25	0	0	0.00
34	6	18	0.13	25	50	0.33	0	17	0.17
36	15	9	-0.07	75	50	-0.33	0	0	0.00
37	9	36	0.30	50	75	0.50	0	17	0.17
38	9	18	0.10	50	50	0.00	17	17	0.00
39	6	30	0.26	50	100	1.00	0	33	0.33
40	3	18	0.16	25	50	0.33	0	17	0.17
41	6	15	0.10	50	100	1.00	0	0	0.00
42	15	24	0.11	75	50	-0.33	17	17	0.00
43	3	30	0.28	0	75	0.75	17	33	0.20
44	18	18	0.00	100	100	1.00	0	0	0.00
45	9	15	0.07	75	50	-0.33	0	0	0.00
46	3	48	0.47	0	50	0.50	0	33	0.33
47	6	33	0.29	25	100	1.00	17	0	-0.20
Mean	**9.0**	**27.5**	**0.20**	**40.5**	**71.6**	**0.52**	**5.2**	**12.1**	**0.07**
N = 29									

Table G-3 – FMCE Pre- and Post-test, Individual Results for Overall Score, Velocity and Acceleration Clusters

ID	Force (1,2) Cluster Pretest	Force (1,2) Cluster Post-Test	Force (1,2) Cluster Norm Gain	Force (3) Cluster Pretest	Force (3) Cluster Post-Test	Force (3) Cluster Norm Gain	Energy Cluster Pretest	Energy Cluster Post-Test	Energy Cluster Norm Gain
4	0	50	0.50	0	100	1.00	50	100	1.00
9	0	31	0.31	17	67	0.60	0	0	0.00
10	0	6	0.06	0	50	0.50	25	0	-0.33
11	6	19	0.13	0	67	0.67	25	25	0.00
12	0	0	0.00	0	33	0.33	0	0	0.00
14	6	19	0.13	17	83	0.80	0	0	0.00
15	0	0	0.00	0	67	0.67	100	50	-0.50
16	13	13	0.00	17	67	0.60	25	50	0.33
17	6	0	-0.07	50	100	1.00	50	50	0.00
18	13	19	0.07	0	0	0.00	25	25	0.00
20	0	6	0.06	0	67	0.67	0	0	0.00
21	13	19	0.07	0	83	0.83	0	50	0.50
23	6	31	0.27	17	17	0.00	25	0	-0.33
24	13	25	0.14	0	17	0.17	0	25	0.25
25	6	38	0.33	17	100	1.00	50	0	-1.00
32	6	6	0.00	0	33	0.33	0	0	0.00
34	0	6	0.06	17	33	0.20	25	50	0.33
36	13	6	-0.07	0	0	0.00	0	25	0.25
37	0	13	0.13	17	100	1.00	75	50	-1.00
38	0	19	0.19	0	0	0.00	50	50	0.00
39	0	0	0.00	0	67	0.67	75	25	-2.00
40	0	6	0.06	0	33	0.33	0	0	0.00
41	0	0	0.00	0	17	0.17	0	25	0.25
42	6	31	0.27	0	0	0.00	0	25	0.25
43	0	6	0.06	0	67	0.67	25	25	0.00
44	6	13	0.07	17	0	-0.20	0	0	0.00
45	0	13	0.13	0	17	0.17	0	50	0.50
46	0	56	0.56	17	50	0.40	0	0	0.00
47	0	19	0.19	0	67	0.67	0	50	0.50
Mean	**3.9**	**16.2**	**0.13**	**6.9**	**48.3**	**0.44**	**21.6**	**25.9**	**0.05**
N = 29									

Table G-4 – FMCE Pre- and Post-test Individual Results for Force 1&2, Force 3, and Energy Clusters

Appendix H – MPEX Analysis

The MPEX as used for this study has been modified slightly. The standard MPEX is geared towards students in introductory university physics courses, and discusses their attitudes towards their courses. As modified the MPEX is geared towards in-service teachers in a workshop setting. A full discussion of the modifications to the MPEX is in Appendix C.

The MPEX was developed using questions that are both positively worded, with expected answers agreeing, and negatively worded, with expected answers disagreeing. The evaluation was originally scored on a five point Likert scale, with five points assigned for a *Strongly Agree* associated with a positively worded question or a *Strongly Disagree* associated with a negatively worded question. Conversely, a *Strongly Agree* associated with a negatively worded question would get a score of one. Neutral answers receive a score of three regardless of the sense of the question. However, the MPEX as used here was scored using a template developed by Michael Wittmann. The template converts the Likert scores to a -1, 0, 1 scoring system by combining scores of 5 and 4 as a new score of 1, a score of 3 as a 0, and scores of 1 and 2 as -1. A score of 1 as produced by the scoring template indicates a question that was answered in the same manner as the “expert” responses used in developing the questions, that is, an answer agreeing with a positively worded question or disagreeing with a negatively worded question. Neutral answers receive a score of 0, and those disagreeing with a positively worded question or agreeing with a negatively worded question receive a score of -1. This process helps reduce the variability in interpretation of "*strongly*" between individuals, and also helps reduce day-to-day variation in personal self evaluation (i.e., do you feel good about yourself today?). The template scores the MPEX in six clusters, as well as assigning an overall score. The clusters describe various aspects of physics learning as described in Table H-1.

	Favorable	**Unfavorable**	**MPEX Items**
independence	learns independently, takes responsibility for constructing own understanding	takes what is given by authorities (teacher, text) without evaluation	1, 7, 12, 13, 16, 25
coherence	believes physics needs to be considered as a connected, consistent framework	believes physics can be treated as separated facts or "pieces"	11, 14,15, 20, 27
concepts	stresses understanding of the underlying ideas and concepts	focuses on memorizing and using formulas	4, 18, 24, 25, 30
reality link	believes ideas learned in physics are relevant and useful in a wide variety of real contexts	believes ideas learned in physics are unrelated to experiences outside the classroom	9, 17, 21, 23
math link	considers mathematics as a convenient way of representing physical phenomena	views the physics and the math independently with no relationship between them	2, 7,15, 19
effort	makes the effort to use information available and tries to make sense of it	does not attempt to use available information effectively	6, 29

Table H-1 -- MPEX Scoring Clusters

Although not precisely the same, the MPEX looks at many of the same aspects of science learning as the STEBI STOE scale. The scores in Table H-2 are a composite score for the workshop participants as a whole. The scores shown are the percentage of possible favorable (score of 1) and unfavorable (score of -1) responses from the workshop participants. These responses are shown graphically in Figure H-1. "Expert" scores would be in the upper left hand corner; an evaluation that *strongly agreed* with every positive question and *strongly disagreed* with every negative question would receive a favorable score of 100, and an unfavorable score of 0. The diagonal line shows the maximum favorable score for each unfavorable value; scores cannot exist above this line.

Pretest			**Post-test**			
Cluster	**Status**	**Score**	**Cluster**	**Status**	**Score**	**St Gain**
Overall Pre	favorable	58.9	Overall Post	favorable	76.6	0.43
	unfavorable	19.8		unfavorable	16.3	-0.18
Indep. Pre	favorable	53.6	Indep. Post	favorable	72.0	0.40
	unfavorable	35.1		unfavorable	22.6	-0.36
Coher. Pre	favorable	50.7	Coher. Post	favorable	61.4	0.22
	unfavorable	25.7		unfavorable	25.7	0.00
Conc. Pre	favorable	64.3	Conc. Post	favorable	87.1	0.64
	unfavorable	14.3		unfavorable	9.3	-0.35
Real. Pre	favorable	74.1	Real. Post	favorable	91.1	0.66
	unfavorable	5.4		unfavorable	4.5	-0.17
Math Pre	favorable	50.9	Math Post	favorable	71.4	0.42
	unfavorable	22.3		unfavorable	20.5	-0.08
Effort Pre	favorable	85.7	Effort Post	favorable	83.9	-0.02
	unfavorable	3.6		unfavorable	10.7	0.07
N=	28					

Table H-2 – Results Of the Modified MPEX
(percent of possible favorable or unfavorable score)

As mentioned earlier this diagnostic was designed for use by university instructors interested in looking at the expectations of their students. As such, we found no studies that used this diagnostic with a group of in-service teachers. However, the pretest scores of this group are consistent with the pretest scores of other groups using this evaluation. Where the literature documents a decrease in expectations from pre- to post-test, this workshop produced a marked improvement in overall score and all clusters except Effort. The Effort cluster is the weakest of the clusters in the diagnostic as determined by the developers at University of Maryland, and modifications of the MPEX removed three of the five questions in this cluster. We don't consider the Effort cluster results significant, so the results are shown for comparison, but not discussed any further.

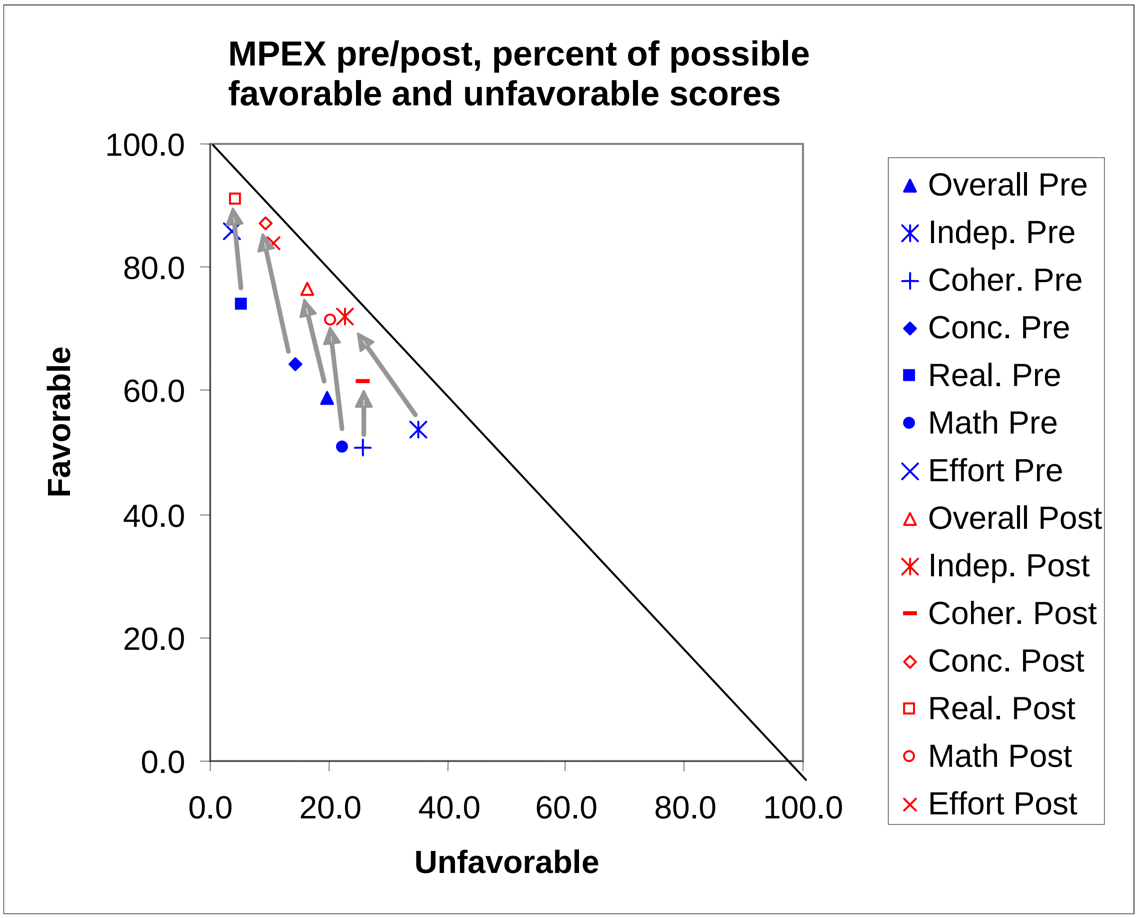

Figure H-1 – Results of the Modified MPEX Pre- and Post-Tests

These scores show a group of teachers who believe that physics is relevant and useful (Reality link) and who feel that understanding the concepts is more important than memorizing facts and using formulas (Concepts cluster). Although they started with fairly strong positions in these areas, they also showed significant improvement. Although their Math cluster scores are not quite as high, their beliefs about using math to represent physical phenomena are still strong and have shown a strong improvement. Results for the Independence cluster are similar to those for the Math cluster, indicating teachers who take responsibility for developing their own understanding of material they will present to their classes. The weakest viable cluster (discounting the Effort cluster) is the Coherent cluster. Here there is no improvement in the unfavorable answers, but still a slight improvement in the favorable score. The workshop, with its narrow focus on force and motion, was apparently not as successful in instilling a solid belief that physics reveals a connected view of how the physical world works.

Although these scores for the entire group show strong improvements and fairly strong final positions, the picture is slightly different for some portions of the workshop group. Individual scores are shown in Table H-4, but must be viewed with caution. This type of diagnostic is subject to a great deal of variability, people view themselves differently from day to day, and individual questions can be interpreted differently by each person. Individual scores should only be used to look at trends, and even then with caution. Here the individual scores are used to group the participants into three groups (top, middle, and low thirds), ranked by overall post-test score. The smaller groups are then analyzed in the same way as before. Table H-3 shows the group results in the favorable/ unfavorable method used in Table H-2.

The data here shows a slightly different picture. While all three groups still have positive gains on the favorable scores and negative gains in most places on the unfavorable scores, the starting and ending positions of the lower third are significantly lower on three of the clusters: Math, Coherence, and Independence. In all three cases the post-test favorable and unfavorable scores are nearly the same, indicating that this group would be much more prone to:

- simply teaching from the text, without real understanding;
- believing that physics is more about facts and equations than it is about understanding the way things work;
- viewing the physics equations and physics concepts as two separate things, with little or no connection.

Figures H-2 through H- 7 show the changes and positions of the three groups. Results in the Concept and Reality clusters are very good for all three groups, with the low third nearly equaling the final position of the high and middle groups. These results indicate a group of teachers who both begin and end the workshop believing that:

- ideas learned in physics are relevant and useful in a wide variety of real contexts;
- they should stress understanding of the underlying ideas and concepts rather than focusing on memorization of formulas and facts.

Pretest Data						Post-Test Data					
Cluster	**Status**	**Score**	**Top**	**Mid**	**Low**	**Cluster**	**Status**	**Score**	**Top**	**Mid**	**Low**
Overall	fav	58.9	70.0	60.5	44.8	Overall	fav	76.6	88.3	77.0	63.2
	unfav	19.8	14.5	14.2	31.4		unfav	16.3	6.9	14.6	28.4
Indep.	fav	53.6	66.7	59.3	33.3	Indep.	fav	72.0	95.0	74.1	44.4
	unfav	35.1	18.3	27.8	61.1		unfav	22.6	5.0	20.4	44.4
Coh	fav	50.7	58.0	55.6	37.8	Coher.	fav	61.4	76.0	62.2	44.4
	unfav	25.7	22.0	20.0	35.6		unfav	25.7	16.0	15.6	46.7
Conc	fav	64.3	74.0	71.1	46.7	Conc.	fav	87.1	98.0	84.4	77.8
	unfav	14.3	12.0	4.4	26.7		unfav	9.3	0.0	11.1	17.8
Real.	fav	74.1	87.5	72.2	61.1	Real.	fav	91.1	100.0	91.7	80.6
	unfav	5.4	0.0	2.8	13.9		unfav	4.5	0.0	2.8	11.1
Math	fav	50.9	67.5	41.7	41.7	Math	fav	71.4	82.5	80.6	50.0
	unfav	22.3	12.5	19.4	36.1		unfav	20.5	10.0	13.9	38.9
Effort	fav	85.7	95.0	72.2	88.9	Effort	fav	83.9	85.0	88.9	77.8
	unfav	3.6	0.0	11.1	0.0		unfav	10.7	10.0	11.1	11.1

Table H-3 – Top, Middle, and Low Third Group Scores, MPEX

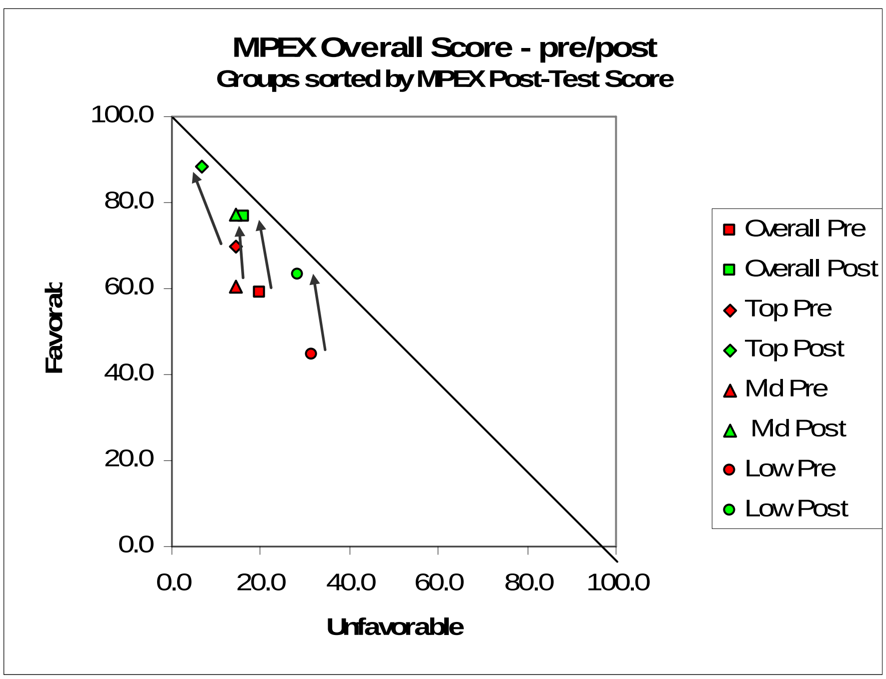

Figure H-2 – MPEX Top, Middle, and Low Groups, Overall Score Top, Middle, and Low Third Groups

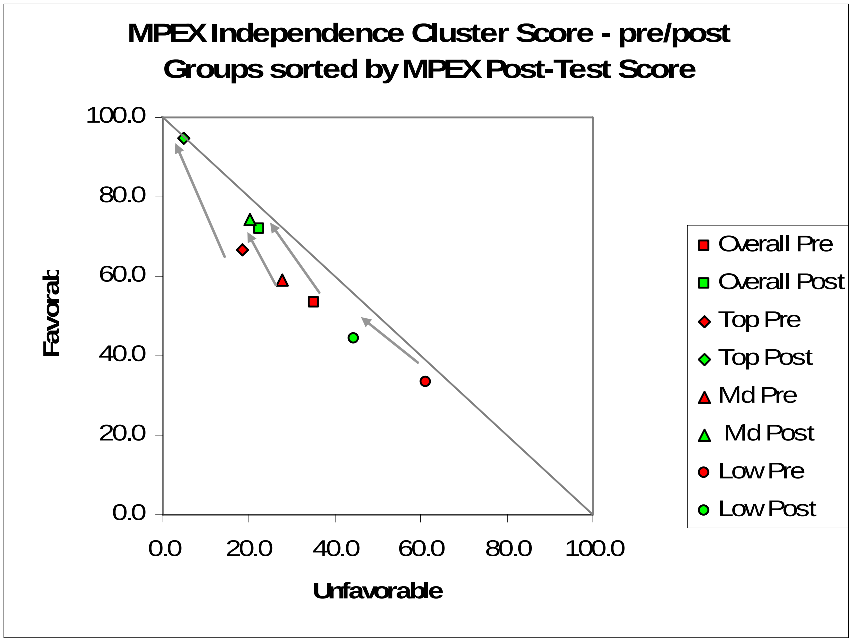

Figure H-3 – MPEX Independence Cluster Score
Top, Middle, and Low Third Groups

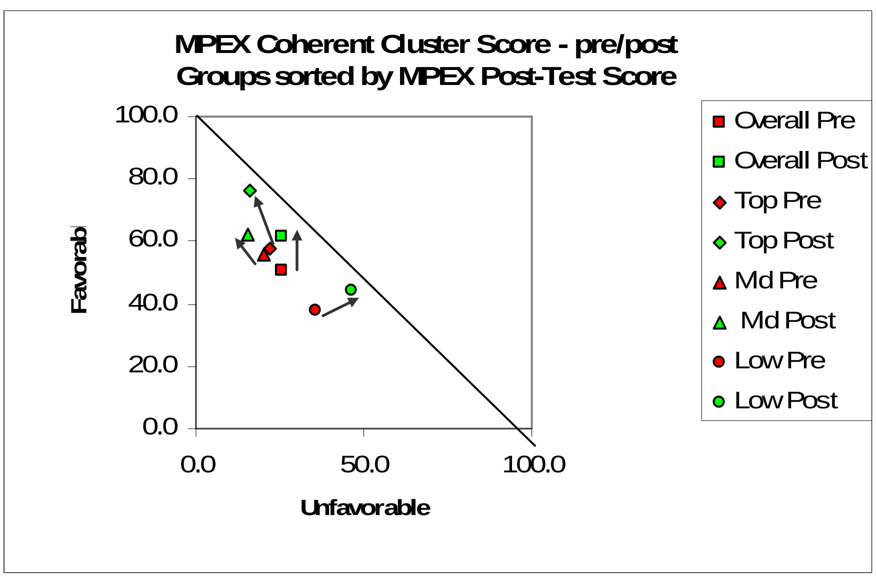

Figure H-4 – MPEX Coherence Cluster Score
Top, Middle, and Low Third Groups

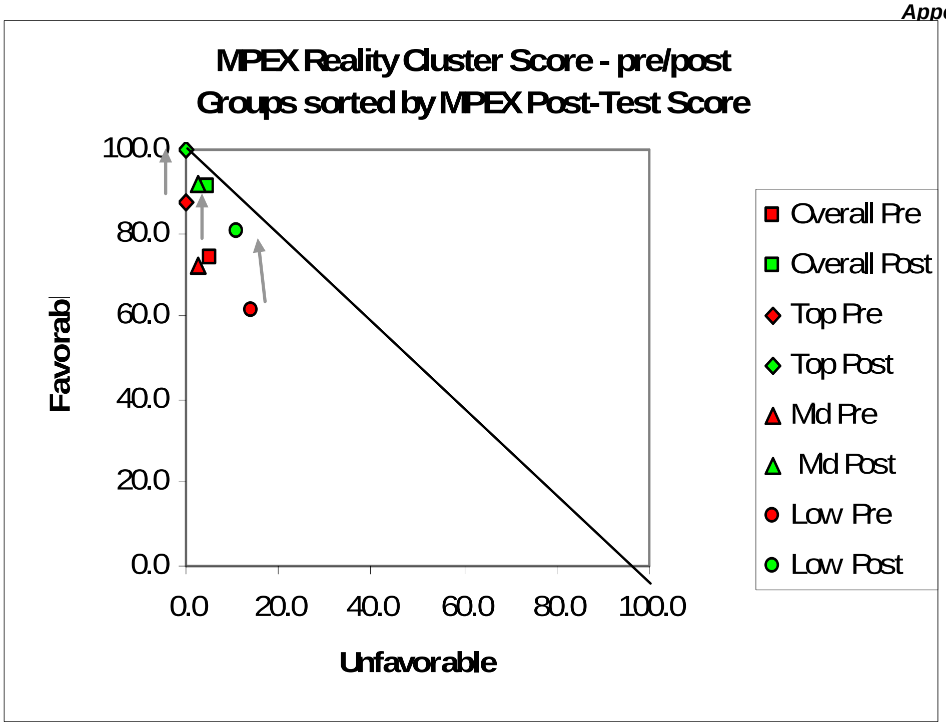

Figure H-5 – MPEX Reality Cluster Score Top, Middle, and Low Third Groups

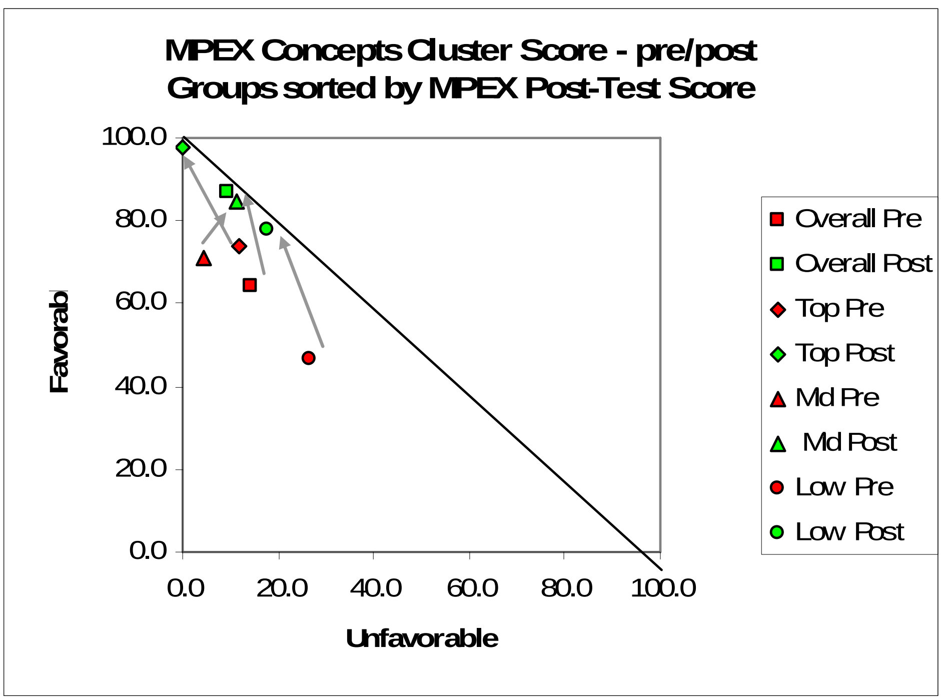

Figure H-6 – MPEX Concepts Cluster Score Top, Middle, and Low Third Groups

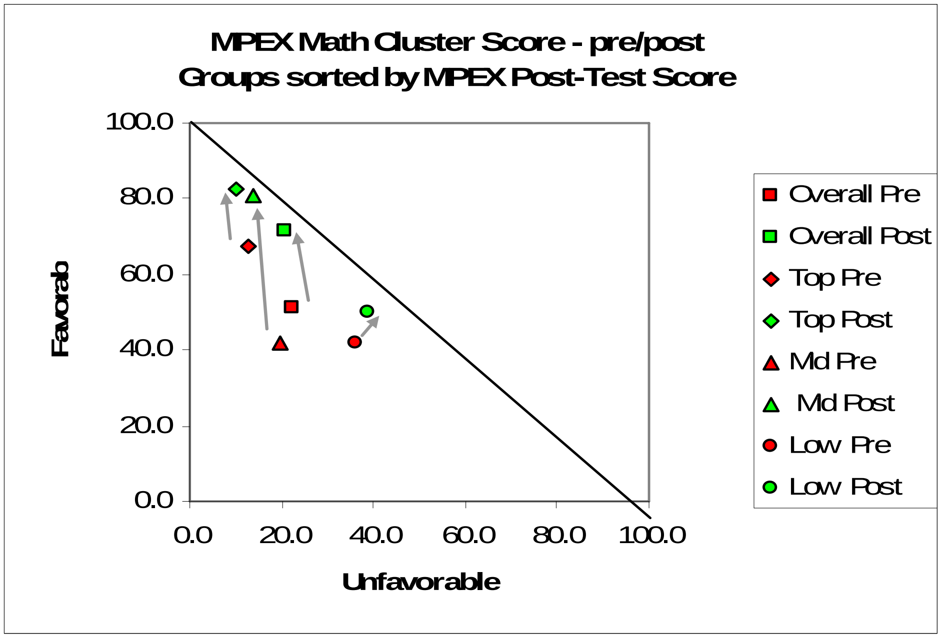

Figure H-7 – MPEX Math Cluster Score Top, Middle, and Low Third Groups

	Pretest		Post-Test				Post-Test						Pretest					
ID	**Total**	**Total %**	**Total**	**Total %**	**Gain**	**Norm Gain**	**Ind**	**Coh**	**Con**	**Real**	**Math**	**Effort**	**Ind**	**Coh**	**Con**	**Real**	**Math**	**Effort**
39	11	37.9	27	93.1	16	0.89	100	100	100	100	100	100	33	40	20	100	50	100
4	26	89.7	25	86.2	-1	-0.04	100	100	100	100	100	0	100	100	100	100	100	100
23	10	34.5	25	86.2	15	0.79	100	60	100	100	100	100	17	40	40	75	0	100
17	13	44.8	24	82.8	11	0.69	100	60	100	100	67	50	67	-40	80	100	50	100
20	15	51.7	24	82.8	9	0.64	100	60	100	100	67	100	50	40	60	75	50	100
37	11	37.9	24	82.8	13	0.72	100	40	83	100	83	100	50	-20	60	100	50	100
42	17	58.6	23	79.3	6	0.50	100	100	100	100	100	100	67	60	100	100	75	100
46	19	65.5	22	75.9	3	0.30	100	20	100	100	67	100	50	60	80	75	100	100
18	7	24.1	21	72.4	14	0.64	100	0	100	100	67	0	0	60	-20	100	25	50
45	12	41.4	21	72.4	9	0.53	100	60	100	100	50	100	50	20	100	50	50	100
Avg	**14.1**	**48.6**	**23.6**	**81.4**	**9.5**	**0.6**	**100**	**60**	**98**	**100**	**80**	**75**	**48**	**36**	**62**	**88**	**55**	**95**
21	11	37.9	20	69.0	9	0.50	100	60	100	75	67	0	33	80	40	100	75	50
41	17	58.6	20	69.0	3	0.25	20	20	33	100	100	100	33	60	80	75	75	100
11	21	72.4	19	65.5	-2	-0.10	80	40	100	100	50	100	100	60	100	100	50	0
25	2	6.9	19	65.5	17	0.63	20	100	100	100	33	100	-17	0	80	0	-75	50
47	18	62.1	19	65.5	1	0.06	60	60	33	100	83	100	83	0	80	100	50	100
44	11	37.9	18	62.1	7	0.39	100	0	67	100	67	0	0	0	20	100	-25	100
43	10	34.5	17	58.6	7	0.37	60	80	17	100	83	100	33	40	60	75	75	100
9	4	13.8	16	55.2	12	0.48	-20	40	50	75	83	100	-17	20	40	50	0	50
38	9	31.0	15	51.7	6	0.30	60	20	67	50	100	100	33	60	100	25	-25	0
Avg	**11.4**	**39.5**	**18.11**	**62.5**	**6.7**	**0.3**	**53**	**47**	**63**	**89**	**74**	**78**	**31**	**36**	**67**	**69**	**22**	**61**
15	-3	-10.3	14	48.3	17	0.53	60	20	67	50	50	50	-33	0	-40	50	-25	50
16	7	24.1	14	48.3	7	0.32	-20	0	33	100	-17	100	0	0	60	75	25	100
32	-4	-13.8	13	44.8	17	0.52	60	-20	100	50	33	0	-67	-20	20	25	25	100
10	11	37.9	12	41.4	1	0.09	20	60	50	50	67	100	67	20	80	75	50	100
24	-2	-6.9	11	37.9	13	0.42	-20	-20	33	100	33	100	-33	0	-40	100	-25	50
12	0	0.0	10	34.5	10	0.34	-100	40	33	100	-17	100	-67	0	80	0	0	100
34	-9	-31.0	9	31.0	18	0.47	-40	-60	67	75	-33	100	-100	-40	-20	25	-75	100
36	11	37.9	5	17.2	-6	-0.55	20	-20	-50	50	33	50	0	20	20	50	25	100
14	6	20.7	3	10.3	-3	-0.50	20	-20	-33	50	-33	0	-17	40	20	25	50	100
Avg	**1.9**	**6.5**	**10.11**	**34.9**	**8.2**	**0.2**	**0**	**-2**	**33**	**69**	**13**	**67**	**-28**	**2**	**20**	**47**	**6**	**89**

Cluster Scores in % of total possible. Ind – Independent; Coh – Coherence; Con – Concept

Table H-4 – Individual Scores, MPEX Overall and Clusters

Appendix I – STEBI Analysis

The basic STEBI results are shown in Table I-1 below. The results for this table are compiled in the manner used by Riggs and Enochs in developing the diagnostic. The evaluation is scored on a 5 point Likert scale according to the favorability of the response, with five points assigned to either a positively worded question with a *strongly agree* answer or a negatively worded question with a *strongly disagree* answer. Similarly one point is assigned to a positively worded question with a *strongly disagree* answer and a negatively worded question with a *strongly agree* answer. Neutral answers are assigned three points regardless of the question wording.

The results are scored on two scales; Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE). The two scales are independent constructs, and are not combined for a total score. PSTE is considered the more reliable of the two.

Our scores are somewhat lower than those found by Riggs and Enochs,[v] but are in line with the PSTE scores reported by Roberts et al[w] in a study of gains seen by in-service teachers as a result of in-service training projects of varying length. Two tailed t-tests for means were performed on both the PSTE and STOE data with a 95% confidence level. The STOE resulted in $p = 0.58$ and the

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[v] I. Riggs and L. Enochs, "*Toward the Development of an Elementary Teacher's Science Teaching Efficacy Belief Instrument,"* Science Education, 74 (6), 625-637, 1990.

[w] J. Roberts, R. Henson, B. Tharp, N. Moreno, "*An Examination of Change in Teacher Self-Efficacy Beliefs in Science Education Based on the Duration of Inservice Activities*", Paper presented at the annual meeting of the Southwest Educational Research Association, Dallas, TX, January 27-29, 2000.

	STEBI Pre and Post-test Results					
ID	***STOE Pre***	***STOE Post***	***STOE Gain***	***PSTE Pre***	***PSTE Post***	***PSTE Gain***
4	52	54	2	54	55	1
9	42	39	-3	50	51	1
10	53	51	-2	64	59	-5
11	44	46	2	49	47	-2
12	41	47	6	39	43	4
14	40	38	-2	34	31	-3
15	42	37	-5	52	52	0
16	45	50	5	36	37	1
17	39	34	-5	48	49	1
18	43	54	11	54	55	1
20	42	39	-3	49	59	10
21	50	48	-2	51	55	4
23	48	53	5	52	51	-1
24	49	48	-1	31	41	10
25	42	45	3	31	43	12
32	46	50	4	34	51	17
34	41	33	-8	47	53	6
43	39	39	0	53	52	-1
37	42	39	-3	57	52	-5
42	36	47	11	52	51	-1
45	40	42	2	56	52	-4
38	41	46	5	46	51	5
36	45	39	-6	50	49	-1
40	41	39	-2	38	48	10
46	44	45	1	50	56	6
44	44	40	-4	45	44	-1
39	41	44	3	50	51	1
41	42	43	1	54	54	0
47	43	42	-1	57	52	-5
Mean	**43.3**	**43.8**	**0.5**	**47.7**	**49.8**	**2.1**
Std Dev	**3.93**	**5.80**	**4.65**	**8.44**	**6.22**	**5.51**

Table I-1 – STEBI Results

PSTE resulted in $p = 0.049$. This indicates the STOE results are not statistically different, but that the PSTE means are.

We also analyzed the data using a procedure like that developed by Wittmann for analysis of the Maryland Physics Expectations Survey (MPEX). This procedure reduces the data to scores of -1, 0 or +1 in order to reduce some of the day-to-day variation in attitudes, and to reflect the teacher's differences in interpretation of answers *agree* and *strongly agree*. The results of this scoring method are shown in Table I-2, and are used in comparisons of STEBI, MPEX and the Force and Motion Conceptual Evaluation (FMCE) data. A score of 11 on the STOE indicates that 11 of the 12 questions in this construct were answered in a manner agreeing with the sense of the question, and one was answered neutrally. A score of 0 indicates that there were equal numbers of questions answered positively and negatively. Positive scores indicate teachers who generally feel that their teaching can influence how well students learn; negative scores indicate teachers who feel that teaching has little influence on their students. Similarly positive PSTE scores indicate teachers who believe their teaching ability will have a positive influence on their students, while a negative scores indicate teacher who feel they personally cannot positively influence their students. In general the STEBI results show only small gains or losses in both the PSTE and STOE scores. The PSTE scores have a higher gain, but most of that gain comes from four scores. As a group, there is very little change from the pre- to the post-test. However, there are strong correlations between some of the STEBI data as shown in Table I-3. The STOE pre- and post-test show a

	STEBI Pre and Post-test Results					
ID	***STOE Pre***	***STOE Post***	***STOE Gain***	***PSTE Pre***	***PSTE Post***	***PSTE Gain***
4	11	12	1	13	13	0
15	6	1	-5	12	13	1
18	7	11	4	13	13	0
20	4	3	-1	10	13	3
43	2	3	1	13	13	0
37	4	3	-1	13	13	0
46	6	7	1	10	13	3
47	6	6	0	10	13	3
45	4	6	2	13	12	-1
38	5	10	5	7	12	5
41	6	6	0	13	12	-1
9	6	3	-3	11	11	0
10	8	9	1	13	11	-2
21	10	8	-2	12	11	-1
23	8	12	4	12	11	-1
39	6	8	2	9	11	2
17	3	-2	-5	8	10	2
34	4	-3	-7	8	10	2
42	0	11	11	12	10	-2
36	8	3	-5	9	10	1
32	5	7	2	-3	9	12
40	4	3	-1	-1	9	10
11	8	10	2	9	8	-1
44	8	4	-4	6	5	-1
12	5	9	4	2	4	2
25	6	8	2	-8	4	12
24	11	10	-1	-7	3	10
16	9	12	3	-3	-2	1
14	3	0	-3	-5	-8	-3
Mean	**6.0**	**6.2**	**0.2**	**7.3**	**9.2**	**1.9**
Std Dev	**2.6**	**4.2**	**3.7**	**6.7**	**5.0**	**4.1**

Table I-2 – STEBI Results Using Revised Scoring, Sorted by PSTE Post-Test

	STOE Pre	*STOE Post*	*STOE Gain*	*PSTE Pre*	*PSTE Post*	*PSTE Gain*
STOE Pre	1					
STOE Post	0.49	1.00				
STOE Gain	-0.15	0.79	1.00			
PSTE Pre	-0.08	-0.02	0.03	1.00		
PSTE Post	-0.07	0.00	0.05	0.79	1.00	
PSTE Gain	0.04	0.03	0.01	-0.68	-0.08	1.00

Table I-3 – STEBI Score Correlations

correlation of 0.49, when sorted by STOE post-test score the results shown in Table I-2 indicate the top third of the group averaged almost 9 points on both, while the bottom third averaged only 3 points. The post-test and gain also show a strong positive correlation of 0.79. When ranking the STOE by post-test score, the top third average a gain of over three points, and the bottom third average a loss of over three points. However, Roberts et al. found problems with the STOE scale of the STEBI, and noted that other researchers had also found problems in that area. They caution against using the STOE to analyze teacher efficacy. This construct may also be affected by recent changes brought on by the No Child Left Behind program, and the reliance on standardized tests to evaluate school performance. Anecdotally many of these teachers complained that they had little ability to affect the material covered in their classrooms, and that their administrations required them to present a great deal of material with very little depth.

There is also a strong positive correlation between the PSTE pre- and post-test scores. On the pretest the top third scored 12 or higher of a possible 13, with an average score of 12.6; the average for the bottom third was a *negative* 1.3. On the post-test the top third scored a slightly lower average of 12.0, while the bottom third averaged a much improved (but still not very high) 4. In both cases the middle third is between the two extremes, but closer to the top. Table I-4 shows the scores for the entire group (Score) and each third as percent of the possible score. This data is also shown graphically in Figures I-1 and I-2.

Pretest					
Scale	**Status**	**Score**	**Top**	**Mid**	**Low**
STOE	favorable	65.5	61.4	67.6	62.0
	unfavorable	15.8	15.2	18.5	13.0
PSTE	favorable	70.8	91.6	85.5	25.6
	unfavorable	14.9	2.8	5.1	33.3
Post-Test					
Scale	**Status**	**Score**	**Top**	**Mid**	**Low**
STOE	favorable	66.7	64.4	62.0	69.4
	unfavorable	14.9	12.9	16.7	13.9
PSTE	favorable	79.8	97.9	87.2	42.7
	unfavorable	9.0	0.0	6.0	20.5
N =	28				
Percent of possible score, groups sorted by PSTE post-test score					

Table I-4 – STEBI Top, Middle, and Low Third Scores

The effect is even more pronounced when the scores are divided into quarters. The top quarter scored a perfect 13 on the pretest and a slightly lower 12.4 on the post; the bottom quarter averaged *negative* 4.5 on the pretest and only 2.5 on the post-test. Normally one would expect some ceiling affect with pretest scores this high, and there may have been some. But in this case more than half of the top third actually had losses rather than gains, and only four of the seven perfect scores remained perfect on the post-test. However, as noted earlier individual scores can vary somewhat day to day, for reasons not connected to the construct. Although interesting, score variations of a point or two are probably not significant.

Finally, there is a strong negative correlation between the pretest score and gain. This is hardly surprising, as the top group had little room to improve, and the bottom group was so low it would have been hard to imagine a decrease. The four scores mentioned earlier that make up most of the gain shown are all in the bottom quarter of the pretest scores. The improvement here takes place in the lower scoring portion of the group, exactly where the most improvement is needed. The PSTE scores suggest that this group of teachers should be more likely to spend the time necessary to develop science concepts in their classrooms, and more likely to choose to teach science when faced with competing demands for their classroom time.

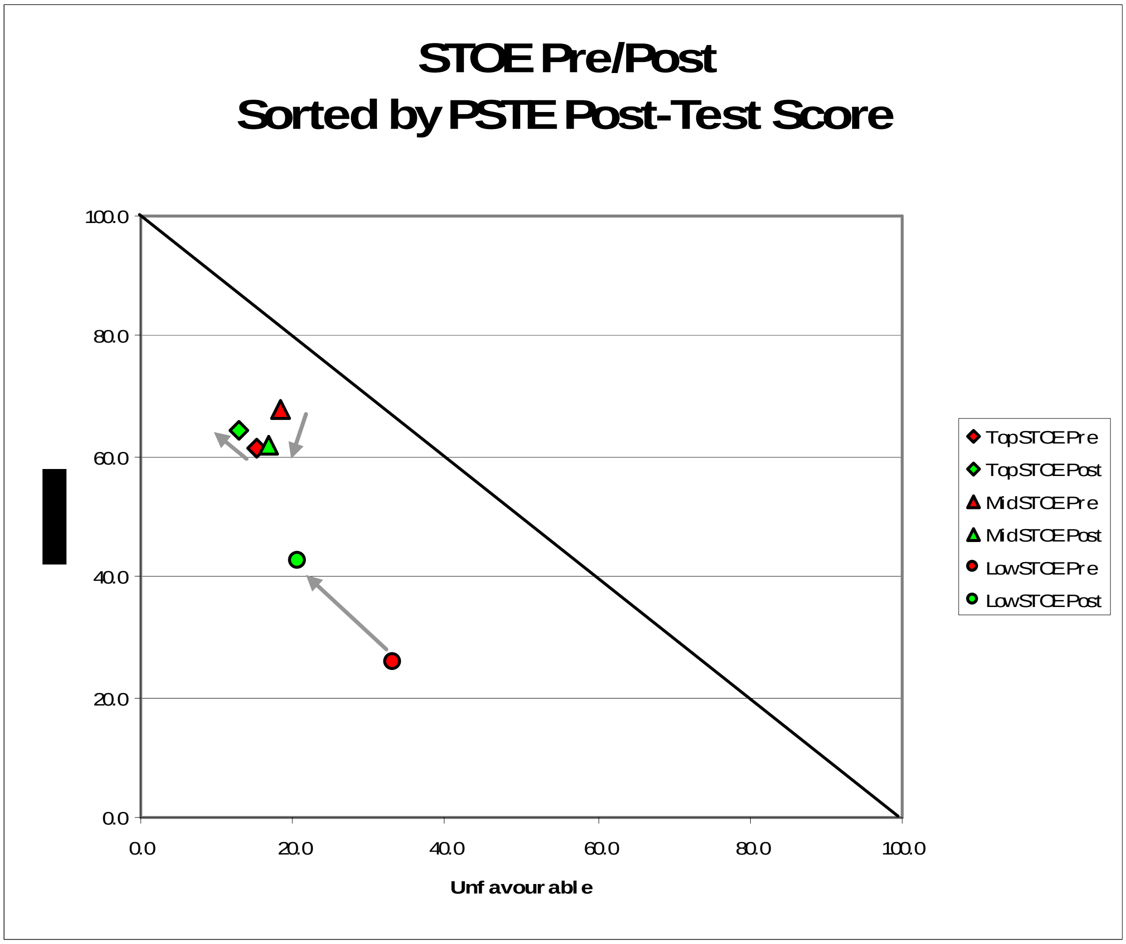

Figure I-1 – STOE Score Movement, Groups Sorted by PSTE Post-Test

Note: Overall scores were nearly identical, (65.5, 15.8) to (66.7, 14.9). They are omitted here to provide clarity in the group scores.

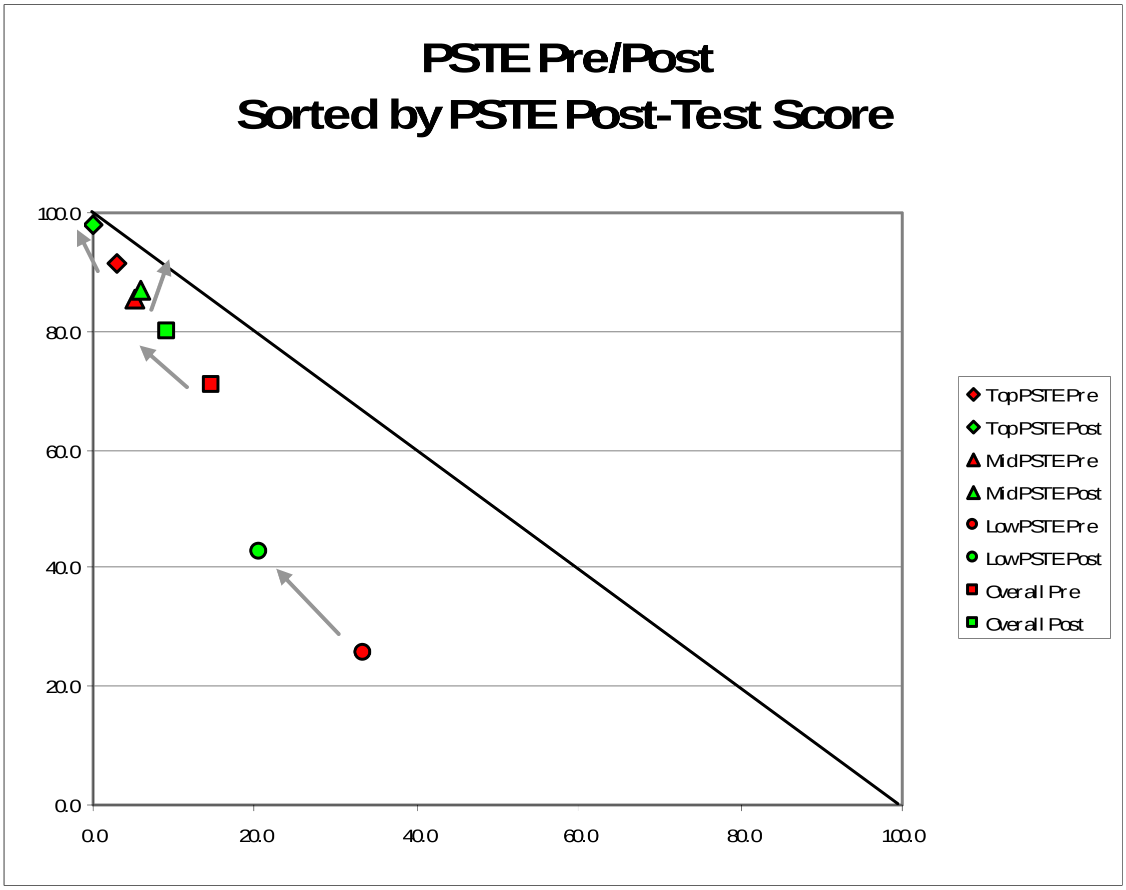

Figure I-2 – PSTE Score Movement, Groups Sorted by PSTE Post-Test

Appendix K – Correlations Between Diagnostics

STEBI	STOE Pre	STOE Post	STOE Gain	PSTE Pre	PSTE Post	PSTE Gain
MPEX Pre	0.09	0.31	0.28	0.51	0.32	-0.45
MPEX Post %	-0.04	0.29	0.35	0.49	0.57	-0.11
MPEX Gain	0.13	-0.26	-0.38	-0.40	-0.31	0.30
MPEX Norm Gain	-0.13	0.08	0.18	0.12	0.37	0.29
MPEX Indep	0.01	0.11	0.11	0.51	0.45	-0.28
MPEX Coherence	-0.13	0.33	0.46	0.34	0.35	-0.13
MPEX Concepts	0.05	0.24	0.23	0.31	0.54	0.17
MPEX Reality	0.01	0.28	0.31	0.11	0.11	-0.05
MPEX Math	0.08	0.33	0.32	0.61	0.62	-0.23
MPEX Effort	-0.24	0.09	0.27	0.08	0.17	0.08
FMCE	0.18	0.15	0.05	0.09	0.07	-0.06
FMCE Pre	0.04	0.03	0.01	-0.22	-0.35	-0.07
FMCE St Gain	0.13	0.13	0.05	0.13	0.18	0.00
FMCE Velocity	-0.03	-0.07	-0.07	0.43	0.36	-0.26
FMCE Acceleration	0.10	0.18	0.14	0.03	0.00	-0.05
FMCE F1,2	0.27	0.44	0.30	-0.02	0.01	0.04
FMCE F3	0.02	-0.24	-0.28	-0.06	-0.09	0.00
FMCE Energy	0.20	0.05	-0.09	0.34	0.28	-0.21

Table K-1 – STEBI Correlations with FMCE and MPEX

	MPEX Pre	MPEX Post %	Gain	Norm Gain	Indep	Coh	Conc	Reality	Math
FMCE	0.41	0.45	-0.38	0.04	0.35	0.53	0.28	0.33	0.19
St Gain	0.35	0.40	-0.36	0.04	0.25	0.53	0.28	0.24	0.19
Velocity	0.27	0.50	-0.45	0.32	0.39	0.45	0.32	0.39	0.24
Acceleration	0.29	0.24	-0.15	-0.06	0.12	0.33	0.05	0.17	0.25
F1,2	0.35	0.27	-0.17	-0.10	0.18	0.23	0.20	0.24	0.19
F3	0.15	0.22	-0.25	0.03	0.21	0.40	0.13	0.11	-0.08
Energy	0.25	0.22	-0.12	0.01	0.21	0.13	0.17	0.09	0.28
FMCE Pre	-0.01	0.03	0.03	0.03	0.14	-0.10	-0.05	0.19	-0.10

Indep – Independence; Coh – Coherence; Conc – Concepts

Table K-2 – MPEX Correlations with FMCE

BIOGRAPHY OF THE AUTHOR

David Nelson was born in Frankfort, Michigan on September 29, 1955. He was raised in Bear Lake, Michigan, and graduated from Bear Lake High School. After attending Michigan State University, Ferris State College, and Northwestern Michigan College for a year each, David enlisted in the United States Air Force (USAF). While in the USAF he attended the University of Illinois, and graduated in 1981 with a Bachelor's degree in Civil Engineering. While stationed at Ramstein Air Base in Germany, David completed a Master's degree in Mechanical Engineering through an overseas program of Boston University, graduating in 1991. After completing a twenty year tour of duty with the USAF David moved to Maine, and entered the Master of Science in Teaching program at the University of Maine in the fall of 2004.

After receiving his degree David plans to teach physical sciences at Erskine Academy in South China, Maine. David is a candidate for the Master of Science in Teaching degree from the University of Maine in August, 2006.