APPENDIX D

Instructor's Feedback

Traditional and Interactive Engagement (IE) Lab Thoughts:

Lab 1: Position – Time Graphs

Traditional:

Part I: Students didn't seem to have any idea why they were doing this section. The idea seems to be that using different sized parts of the "picket fence" still give the same speed, but the students aren't familiar enough with the detectors to know what 's going on with them. So they just push the carts and write down numbers.

Part II: This section works pretty well; it gives them the feeling for how their motion affects the graphs. Calculating the slope of the last graph was fairly useless though, because it didn't relate to anything. Most students only got this far through the lab.

Part III: This section was okay for the one group who got to it.

Part IV: No one made it to this section.

Part V: No one made it to this section.

Generally, the various parts seem disjointed – from carts to people to carts to people. The students got a lot out of Part II, but Part I took so long that they couldn't get past the second section. For most people, this lab basically consisted of Part II.

IE

The Science Workshop file for Activity 1-1 (L1A1-1) had a bug, that the motion sensor either wouldn't work at all, or would take from 20 seconds to several minutes to begin working. Closing the file, opening a new experiment and configuring it solved the problem.

Generally the lab worked well. The graph matching activities (L1A1-2, L1A2-2) were slightly confusing because the graphs in the book did not match the ones on the computer. Since some of the questions referred directly to the motion in the lab book, this caused some confusion.

Several students were unable to correctly answer Question 2-1 (Activity 2-1), about how slow versus fast motion showed up on the graph. They correctly described the difference between slow and fast motion, but not how it showed up on the graph as the distance from the time axis. This seemed to be the concept that the students had the most difficulty with here – the difference between velocity being the slope of a position graph, and being the value of a velocity graph.

Most students made it through Activity 3-3; a few only made it through Activity 2-2.

Lab 2: Changing Motion

Traditional:

This lab worked out well; most students finished the whole lab. Once the students understood the directions defined by the motion sensor, they were able to work with the graphs. The fact that the lab was short enough to complete in the time available meant that there was time to work with students on the meaning of motion graphs, and to compare position, velocity and acceleration graphs. This provided an important connection to lecture, and a good learning opportunity.

IE:

This lab worked fairly well. Most students did not finish, but most did get at least through Activity 3-1 or 3-2. Much of the time was spent becoming familiar with the software and how to analyze graphs, and a lot of time was spent on understanding the graphs, which was good. I did Extension 2-3 “Using Statistics” with most groups individually, so that they would learn how to find velocities and accelerations from the means and slopes of graphs. As expected, velocity graphs were difficult for the students after becoming familiar with how position graphs worked, but since that was the point of the lab it was good that the students spent the most time understanding that.

Lab 3: Force and Motion

Traditional:

No one made it past Part II; some never made it past Part II #7. Part III, if anyone had gotten there, seems to be missing a Step 5: Fit a line to the graph. Record the slope as the mass of cart & sensor (slope). It should also have a Step 6: Calculate the percent difference between the two values for mass.

Part I seemed to take a long time (30 – 45 minutes) for a section that didn’t seem to explore any deep physical concepts. The idea that the regression line was a model for the data didn’t seem to be universally understood, especially the meaning of the intercept. In Part II, Step 10, students were very confused about why they were measuring the force on a cart that wasn’t moving.

Generally the lab went well (as far as students made it). They did gain some understanding of modeling data with an equation. However, since so much time was spent in Part I at the expense of Part III, they didn’t gain much new understanding of the relationship between force and acceleration.

IE:

I did Activity 1-4 with the students as a group to start the lab, since the calibration in the book is very different from the actual method they need to use. They made it through the lab pretty well; some made it all the way through.

The big problem with the lab was the calibration of the force sensors. Between Activities 2-2, 2-3 and the run with another mass to fill out Table 2-3, the calibration would sometimes change, so that the results were rather random. Also, the experiment files have a calibration that gives a result of acceleration being proportional to the negative of force. So we had to change the calibration to a low value of 2 N and a high value of 0 N. Since the point of the lab is the (positive) proportionality between force and acceleration, this was a bit of a problem.

Lab 4: Combining Forces

Traditional:

No one made it past Part II, so there never really was a combining of forces. Most of the acceleration versus force graphs came out well, so they did at least see that force and acceleration are proportional.

IE:

There were some calibration problems again, so that sometimes force and acceleration had opposite signs. Fortunately the people who had this happen to them noticed that it was wrong, so they learned something. Activity 2-1, where they hook a spring scale to a cart and pull it with constant force, was nearly impossible on our tracks. The part with two spring scales was impossible, and impossible to compare to one spring at twice the force. Only one group made it through Activity 3; one group only made it through Activity 1. Most made it partway through Activity 2. But they did seem to get the idea that force and acceleration are in the same direction, and are related in their sizes.

Lab 5: Force, Mass and Acceleration

Traditional:

This lab worked fairly well; most groups were able to finish. For some groups the graph of a vs m was not really an inverse, but most graphs of a vs 1/m were fairly good. Some of the fitted lines had non-zero intercepts which the students had a hard time understanding.

IE:

All students made it through this lab, which made them feel better about it. Several students' data lead to acceleration vs mass graphs that were linearly proportional rather than inversely proportional. This of course caused confusion for them and for me, since I could see nothing they did wrong. Investigation 2 did not go as well; the ratio F/a did not always equal the measured mass. Activities 2-2 and 2-3 were not real interesting for the students, as we had already covered Newton's second law in lecture, and they were happy to simply apply that rather than using their investigations to discover it again.

Lab 6: Gravitational Forces

Traditional:

Somehow this lab took a lot longer than it seemed like it would. Amazingly, even the picket fence part took some students a long time. Most made it through Part VI, but no one made it through Part VII. Sign problems were a problem for this lab, with the students becoming used to the direction of motion in Parts II and III, which then changed in Part IV. Most of the calculations of g worked out pretty well, even in Part VI. Unfortunately the students were rather rushed through Part VI (I told them to try to get through that section), so they were unable to spend the time they needed to understand what it was really getting at.

IE:

This lab started out well and lost focus toward the end. Investigation 1 was a good review of motion graphs, which students had begun to forget (since we'd already had a test over them). The value of the acceleration due to gravity came out well, and all was good. It would have been nice to do Extension 1-4, since those activities were done in the traditional lab. Investigation 2 did not go so well. The students did not understand the idea that they were trying to "discover" gravity; they seemed to think they'd already noticed gravity before. They did not understand that gravity is an "invisible" force and that the force of gravity is a model we use to explain why things fall. The questions at the beginning of Activity 2-1 were just confusing, since they had no idea what it meant to "invent" gravity, and the questions were worded in a confusing way. The questions in Activities 2-2 and 2-3 really seemed to have little relationship to anything else done in the lab, which suited the students fine because they did relate to things done in class that the students remembered how to do. Investigation 3 seemed unrelated to the rest of the lab, and most of the students who actually got that far (about half) thought it rather goofy. They had no idea of what was meant by a mechanism for an object to apply a normal force, and they seemed surprised that after adamantly focusing on observable quantities the lab book would suddenly expect them to think in terms of microscopic mechanisms (without "inventing" them).

Lab 7: Passive Forces and Newton's Laws

Traditional

The lab was a good length; everyone made it through the whole lab. This was a good review of forces and vector diagrams, things that had been done several weeks ago in lecture. Most students were able to remember these concepts, although it would have been nice to have them derive the formulas for the coefficients of static and kinetic friction themselves. Some of the students did not work through the given derivations sufficiently to really understand why the various terms were in them. The analysis of kinetic friction was made more difficult by the fact that the derivations of kinetic friction force and the coefficient of kinetic friction (in Parts III and IV) are wrong. Since both masses are moving, the mass in Newton's second law is the mass of both the block/sensor and the hanging mass. So the value of "m" in the expression for f_k in Part III should be the mass of both masses. In the expression for μ_k in Part IV, the "m" in the numerator should be the sum of the masses, while the "m" in the denominator should be the mass of the hanging mass. Since the hanging mass changed in Part IV, Step 4, the results gave the impression that the coefficient of friction depended on speed.

IE

This lab was a little long. Most students made it into Investigation 3, although no one made it past Activity 3-2. Some students did not make it past Activity 2-1. Again in this lab, the students did not understand the idea or the need for "inventing" forces (as in the gravity lab). Questions 1-4 and 1-5, which are the summary points of Investigation 1, ask the students to "invent" friction as a means of "saving" Newton's second law. This is confusing, however, since the idea of a frictional force has been used since the first page of the lab (and extensively in lecture). So the students (understandably) do not understand the need to invent something they've already been using, and Questions 1-4 and 1-5, rather than summarizing and clarifying the investigation, simply confuse the students and bring the lab to a grinding halt. Investigation 1 is already difficult and confusing in itself, without the "invention" problem. It is very difficult to achieve constant velocity with the friction pads, so we're forced to try different amounts of friction, and assume that somewhere in that range there will be a value of friction that actually achieves zero acceleration. It is also confusing to the students that the force measured by the force sensor is less while the cart is moving (accelerating) than while at rest, even though the same applied force (the weight hanging on the string) acts. Unfortunately this point is never addressed in the Investigation. The students notice this effect, however, and are expecting to analyze that problem when they're confronted by the "invention" questions, and this adds to the confusion.

Investigation 2 works fairly well, in that the students can see Newton's third law working. However the skateboards have such poor bearings that it takes more than 50 N to pull even the lightest people on them, so they cannot really see Newton's third law at work with the skateboards. In Investigation 3, the students have great difficulty with questions like Question 3-2, which ask about a mechanism for explaining the transmission of tension along a rubber band. This question asks for an answer so far removed from what they've been thinking about and working with in the lab that few if any students are able to even understand the question without a lot of help, and the question feels rather unfair to students who think that their investigations should help them answer the questions. No one has been able to think about a microscopic mechanism without a lot of direction.

Lab 8: Newton's Third Law and Conservation of Momentum

Traditional:

Most students made it through Part III, some finished this lab. Surprisingly, some force sensors show a marked "bounce" after impact while others do not. So some graphs of Force versus Time were not very similar. Trading sensors around till students had matching sensors helped a lot. In general the lab went well, with Newton's third law being pretty obvious in Part I and momentum being conserved fairly well throughout.

IE:

There was a software problem in this lab. The "Collisions L9A1-1" experiment was set to start taking data when a force sensor activated. The problem, however, was that it took a fairly large force to activate the data recording, so initially all they saw was the very end of the force being exerted, and maybe the bounce. So I removed all start and stop conditions. The instructions are vague and irritating on the aspect of calibration – they say to calibrate and give enough instructions about it to confuse the students but not enough to actually explain how to calibrate. They mention here (and in other labs) to hang a 1-kg mass from the force sensor to calibrate it. Naturally this confuses students who know how we normally calibrate the sensors with spring scales, but who feel compelled to follow every instruction in the manual. So I discover groups taping masses to their force sensors (which they had previously calibrated with spring scales).

This lab actually went very fast, and most students finished a half hour early. I wish the lab had done more collisions and had the students calculate more momenta. There was no reason not to, and it would have made the lab more similar to the traditional lab. Using one inelastic collision to verify momentum conservation seems rather sparse.

Lab 9 (10): Two-Dimensional Motion

Traditional

The students had a lot of fun with the projectile motion launchers in this lab. Unfortunately no one was able to finish the lab. Most students made it only partway through Part II. In Part II it was very difficult to see the marks made by the ball on the low angle, and the differences among the Average distance, Paper distance and Total distance confused several students. As in a lot of these labs, it would have been nice to put the range equation near the beginning of the section, to tell the students where they are going, rather than at the end of the section to tell them what they were supposed to get. As it was the students converted their graphs of range versus angle to range versus the sine of twice the angle without knowing why they were doing it. I would have preferred doing Part IV before Parts II and III, since this was closer to what we'd been doing in class. This is definitely a lab that would have been more beneficial had they gotten farther through it.

IE:

This lab was a pretty good length; everybody finished. The motion graphs at the beginning were a good review, although a discouraging number of students had forgotten how graphs looked for accelerated motion. It would have been nice to put this lab in before the labs on forces – it would have provided a good lab on projectile motion while we were doing it in class. The students were surprised that all of a sudden there were a lot of calculations to do, since these labs had generally avoided calculations in all other labs. The students had problems keeping a consistent "tapping" going to accomplish good two-dimensional motion. The resulting motion usually ended up looking a lot like projectile motion, but the graphs were not well fit by a parabola. It would have been nice to have a little more discussion or analysis of the results; it seemed for the first time in this lab book that the students simply took data, analyzed it with some calculations, and finished.

Overall Thoughts:

When I first taught these labs in the spring of 2001, the students in the traditional lab definitely expressed to me more positive opinions of the labs than students in the IE labs. This seemed to be because students in the traditional labs could at least tell what concepts they were working on, even if they couldn't finish the lab, while students in the IE labs often had no idea what they were doing or what they were supposed to get from the lab if they couldn't finish it. In the fall of 2001, neither lab expressed strong positive or negative opinions of the labs. The IE lab group did seem to react strongly to "inventing" forces and mechanisms; they did not seem to like this practice.

In thinking about the labs, it seems that there are two ways to approach a physics laboratory experience: One way is to prepare a set of experiences that the student can work through to come to an understanding of a concept, the other way is to try to model the process of doing physics by designing an experiment, calibrating measuring devices, taking and analyzing data and coming up with a conclusion. The IE labs clearly approached lab in the first way, while traditional labs generally approach it in the second way. Either way can be useful to the student, but the IE labs would have been more effective, I think, if the students had a more clear idea going into the lab what concepts they were trying to work with, and if they could be sure to finish the process. As it was, the IE labs often felt like a set of rather unconnected experiences, which the students would hopefully put together into one conceptual framework. There was no well-defined beginning, middle and end; there were only as many experiences as the student could get through in two hours. The transitions between exercises within a lab made sense to me, but the students never noticed them and often asked about what they were doing and why.

The traditional labs also suffered from this problem, but even more so. Traditional labs usually have a beginning (deriving some equation, designing an experimental set-up, calibrating the instruments) a middle (taking data, analyzing it in graphs and/or equations, coming up with a result) and an end (calculating errors or uncertainties, writing conclusions). These traditional labs had no such parts. They were simply the IE labs without the connecting prose and questions, so there was even less to guide the student through the lab and show why they were doing what they were doing. In some cases this lack of excess verbiage actually helped the students see the "big picture" of what they were doing, but in my opinion it did not make these labs "traditional".

To use the IE labs effectively, I think that the instructor needs to be able to vary the way time is spent in lab and in lecture. Instead of having one two-hour lab each week and three lectures, an effective use of time would be to spend one whole week doing several of the labs, and then a few weeks without doing any labs. As it is, if the lectures continue at their normal pace, the students are well past the concepts covered in many of the labs by the time that they do the lab, and the exercises seem like a tedious chore to develop something that the students are already familiar with. On the other hand, if the lectures keep pace with the labs, then the amount of material covered must change dramatically. It may be nice to spend three weeks developing Newton's Second Law and over five weeks with forces, but this is at the expense of a good coverage of momentum, and all mention of rotations, torque, and oscillations. To say that IE labs do a great job of teaching forces is not really fair, since I could produce students expert at almost any topic if I spent five weeks on it. I think that to really use the IE labs effectively, the instructor must be able to modify the class schedule and spend more time in lab some weeks and less other weeks. The three lab series on Newton's Second Law would be much more effective if it was done all in one week, instead of lectures. This way the students could develop a conceptual understanding of Newton's Second Law in a coherent way, and not have it interrupted by the intervening weeks and the lectures in between. After the series on Newton's Second Law, then the labs could be replaced by problem solving sessions involving forces.

Since the IE labs spend so much time on the conceptual basis for Newton's Second Law, it is not surprising to me that the students would do well on the FCI after doing the labs. I have the feeling that they paid for this by being less able to do calculations and problems in the other ten chapters of the book we covered. The IE labs almost seemed written with the FCI in mind. Since the traditional labs did not have the conceptual emphasis to them that the IE labs did, it is not particularly surprising to me that students in those labs would improve less on the FCI. Unfortunately, since the traditional labs still covered the same topics as the IE labs and did not cover the concepts missed by the IE labs, the students did not get the benefit of practice with calculations for the topics missed by the IE labs. So the experiment seems a little biased toward improving the FCI scores of students in the IE labs.

In future versions of this experiment, I would like to see real traditional labs compared to the IE labs. And a more fair way to compare, I believe, would be to use the FCI as well as a quantitative test that emphasized problem solving and calculations. With the importance of calculations and problem solving in physics, this would seem a more complete test of how well the labs helped the students to learn physics. I would also suggest that since physics is much more than forces, comparison tests between traditional and IE labs should contain more topics than what is covered in the FCI.

I think overall that an ideal lab situation would make use of both types of lab. Some concepts, like Newton's Second Law, need a lot of hands on time to develop a conceptual understanding, while the traditional way of approaching this concept in lab involves a lot of tedious calculations that do not seem to help the students' conceptual or quantitative understanding. Traditional labs, however, could better cover other topics, and I think the students can gain from the traditional approach of modeling the way physics is done in the lab. If I was to use the IE labs in my own lab, I would probably mix them in with traditional labs, and modify the time I spend with them if possible.