CHAPTER 10: Evaluation of Student Expectations

I. OVERVIEW

A. What are expectations?

Students bring to introductory physics classes more than just common sense beliefs about how things work. They also bring assumptions, beliefs and attitudes about the nature of what they are learning, the skills they need to succeed, and what they need to do to achieve success. As previously discussed in chapter 2, these cognitive "expectations" can affect how students respond to an introductory physics course. Students' expectations affect what students choose to listen to and what they ignore in the firehose of information provided during a typical course. Students' expectations also affect how students build their own understanding of the course material and the type of understanding they build. All of this plays a major role in what students take away from a course.

B. Why study expectations?

Although we don't often articulate them, most physics instructors have expectation-related goals for their students. In the calculus-based introductory physics courses, we try to get students to make connections, understand the limitations and conditions on the applicability of equations, build their physical intuition, bring their personal experience to bear on their problem solving, and see the link between classroom physics and the real world. These kinds of learning goals — goals not listed in the course's syllabus or the textbook's table of contents — are part of the course's hidden curriculum. Even when articulated explicitly, course goals like these are often not adequately reinforced through testing and grading. Yet, they are key components of our main goal of helping students learn a useful, functional understanding of physics.

As instructors, we are frustrated by the tendency many students have to seek "efficiency" — to achieve a satisfactory grade with the least possible effort — often with a severe unnoticed penalty on what and how much they learn. In the examples of Hammer and Tobias in chapter 2,[1] the structure of the traditional lecture course seemed to encourage students to pursue this so-called efficient strategy. These traditional lecture courses emphasized algorithmic problem solving. This played into students' beliefs that conceptual understanding and problem solving are separate and that the latter is more valuable for success in the course. The courses also discouraged debate and discussion of the course material. Understanding and cooperative learning were not valued by the course format. Some students with expectations more favorable to achieving our main goal of functional understanding, those that tried to make sense of the course material for themselves, did not find their efforts supported or encouraged by their courses.

In the same way that research into students' understanding of physics concepts has resulted in new curricula which improve students' conceptual understanding of physics, it is hoped that better awareness and understanding of the role of student expectations in introductory physics can lead to further improvements in instruction. Although most studies, including Hammer's, are short term and show no evidence that students change their expectations over time, there are some indications that such changes do occur. In the long term studies of Perry[2] and Belenky *et al.*[3] (described in more detail in chapter 2), they frequently found their young adult subjects starting in a "binary" or "received knowledge" stage in which they expected everything to be true or false, good or evil, etc., and in which they expected to learn "the truth" from authorities. Both studies observed their subjects evolving to a "consciously constructivist" stage. In this stage, the subjects accepted that nothing can be perfectly known, and accepted their own personal role in deciding what views were most likely to be productive and useful for them. In introductory physics courses, the analogous situation to the evolution of students' general epistemology is a change in the way students view physics and what they do to learn it. For example, we would like students to see physics as less of an exercise of taking disjointed facts and problem solutions handed down by authority (as represented by the instructor and the textbook) and more of an internal process to build a deep understanding of a few key concepts that can be used to understand many situations in the students' real world. In this "constructivist" physics stage, students do not just accept the pieces they are given by authority but try to make sense of it for themselves and fit the pieces into a coherent framework.

C. Description of Study

This study is one attempt to better understand the evolution of student expectations towards the constructivist physics stage and on how student expectations are affected by traditional and enhanced instruction. To evaluate the distribution and evolution of student expectations in different types of courses, we developed the *Maryland Physics Expectations* (MPEX) *survey*, a Likert-style (agree-disagree) questionnaire designed to probe some aspects of these cognitive expectations (see chapter 5 for more information on the development and validation of the survey).[4] For this study, the MPEX survey was used to measure the distribution of student views at the beginning of introductory calculus-based physics classes (pre), at the end of the first semester or quarter (mid), and at the end of the first year (post) for classes using the three research-based curricula and traditional lecture instruction (the curricula and implementations are described in chapter 8). I distributed, collected, and processed MPEX surveys from the ten colleges and universities participating in this study. Other members of the Physics Education Research group at University of Maryland checked the processed data for accuracy against hard copies of the students' responses. The data was analyzed by Redish, Steinberg, and the author using both traditional and innovative techniques (see the description of the Redish plot in section E below and in chapter 5). I conducted interviews with students at five of the ten schools including at least one school using each or the three research-based curricula. The schools involved, the teaching methods used, the number of students in the sampling, and the types of data taken are summarized in table 8-4. (Summary descriptions of the schools, courses, and course contents can be found in tables 8-1, 8-2, and 8-3 respectively.)

D. Research Questions

Because so little is known about the distribution, role, and evolution of student expectations in the university physics class, many questions can be asked. To limit its scope, this chapter is restricted to three questions.

- Q1. How does the initial state of students in university physics compare with the views of experts?
- Q2. To what extent does the initial state of a class vary from institution to institution?

Q3. How are the expectations of a class changed as the result of instruction with the three research-based curricula as well as traditional lecture instruction at our ten participating schools?

Other questions, such as how individual students' expectations evolve, the relationship between student expectations and success in the course, and how the survey results compare with other evaluations of student learning are left for further analysis and future studies in this area.

E. Explanation of the MPEX survey results

Although the survey itself uses a five point Likert scale (strongly disagree = 1 to strongly agree = 5),[5] we have chosen to group the student responses into three categories: agree, disagree, and neutral. The reasons for this transformation are discussed in chapter 5.

As described in chapter five, the responses of undergraduate physics instructors committed to implementing research-based active learning teaching methods in their own classrooms are considered here as expert responses. Almost 90% of our expert responses agreed with a particular position for each survey item.[6] The preferred responses of our expert group are defined as the "expert response." A response in agreement with the expert response is defined as "favorable" and a response in disagreement with the expert response is defined as "unfavorable." When data is presented in tables it will be presented as (% of favorable responses) / (% of unfavorable responses).

The "agree-disagree"(A-D) or "Redish" plot introduced in chapter five is also used to display the MPEX. In these plots, the percentage of respondents in each group answering favorably is plotted against the percentage of respondents in each group answering unfavorably.   More detailed comments on how to read a Redish plot can be found on page 167.

In addition to the overall result, the MPEX survey has clusters of items that probe six dimensions of expectations (described in detail in chapter 5): concepts, independence, coherence, reality link, math link, and effort. The first three dimensions were used by Hammer (see chapter 2)[7] to classify student beliefs about the nature of learning physics. The survey items are described in chapter 5. A full copy of both the scantron and pencil & paper versions of the survey are included in Appendix B.

In order to eliminate the confounding factor of differential dropout rates from the evolution of student expectations, unless otherwise specified, the MPEX data presented in this chapter is matched.[8] Our results show some differences among different classes at the same institution, but the variation is statistically consistent with the sample size. To simplify the presentation of the MPEX results, the individual class results have been combined for similar classes at a given institution.

F. Site visits and Interviews

During the course of this investigation, I conducted over 120 hours of interviews with student volunteers at the University of Maryland, the Ohio State University, Dickinson College, Drury College, and Nebraska Wesleyan University. The interviews followed the MPEX survey or the Open MPEX open protocols described in chapter 7. The students were interviewed individually or in groups of two or three. If there was sufficient time the students were asked to work individually on a problem as a think aloud exercise (see chapter 7), usually the two-rock problem described in previous chapters. These interviews were conducted mainly to validate the students' interpretations of the MPEX survey items and to understand the reasons behind their answers. The interviews also revealed a great deal about the students' expectations and their perceptions of the material and the teaching method used. The interviews with the students at the Workshop Physics schools were particularly interesting and are discussed in detail later in this chapter.

G. Chapter Layout

In section II, I present the distribution and evolution of student expectations obtained with the MPEX survey from introductory calculus-based physics sequences at each of the ten schools. Both the overall survey results and the results from the six dimensions or clusters are discussed. For each survey dimension, the pre student responses are compared with the following:

- with the expert responses to address question Q1,
- with each other to look for differences in student populations to address question Q2, and
- with the mid and post results to look for changes to address question Q3.

In section III, expectation results from interviews with students at three of the schools using Workshop Physics (Dickinson, Drury, and Nebraska Wesleyan) are discussed in detail. Note that this includes the school where the Workshop Physics curriculum was developed (Dickinson) and two secondary implementations.

Section IV is a chapter summary going over the results in the context of the three research questions and discussing the implications of the results.

II. STUDENT EXPECTATIONS: DISTRIBUTION AND EVOLUTION

To understand the effects of the instruction in the introductory physics sequence on students, one needs to measure the initial state of the student coming into the sequence and their state at later times during the sequence. In this section, we discuss the pre, mid, and post sequence results obtained from students taking the MPEX survey in the calculus-based introductory physics sequence at their institution. A summary of the schools, classes, and the number of students surveyed is shown in Table 10-1.

Pre MPEX survey data from our "expert group" and the US Physics Olympics Team from are included for comparison with the students' initial state as measured by the pre results. To better compare the pre results with the later measurements, the pre-course data presented here only includes students who took the survey at the beginning and end of the first semester or quarter of introductory physics.[9] Thus, these pre student responses are only from students who completed at least the first course in the sequence. The overall pre results and the pre results from the six clusters are presented in Table 10-2. To observe differences in the initial state at different schools, the University of Maryland data is used as a baseline. A school whose MPEX score is at least 2σ different from Maryland is considered significantly different. (The estimation of the uncertainty σ is described in chapter 5)

The matched pre/mid and pre/post MPEX survey results are used to learn about the effects of the different methods of instruction on student expectations. The two types of matched data are included for the following reasons. Data matched over one semester allows for a more controlled study. Since over one semester or quarter

Table 10-1

Table 10-2

Table 10-3

Table 10-4

students have only one instructor, this allows us to look at the effect of a single teaching style on a particular class. Matched pre-mid survey results are shown in Table 10-3. (Because of logistical problems, no mid MPEX data was collected from the traditional class at Carroll College.)

Although the introductory courses participating in this study vary in content, they all begin with Newtonian mechanics. While there are some differences in content coverage, for the most part all the first term courses cover the same main ideas and concepts. This allows for a large degree of control for comparing classes and allows us to focus on the effects of the implementation of a curriculum by a particular instructor. However, my interviews and observations by the members of the University of Maryland PER group suggest that for at least some students, more than one semester or quarter may be needed to produce significant changes in student expectations.

The pre and post matching over one year allows us to look for longer term effects. A period of one year allows us to look at student responses from the beginning and end of the introductory sequence at all the participating schools except University of Maryland. Although the University of Maryland sequence has three semesters, post data is used from the end of the second semester so that all students reported on in this section will have had approximately equal class time. For eight of the ten schools matched pre/post data are presented in Table 10-4. Because of logistical problems, no post MPEX data was collected from the Workshop Physics classes at Skidmore College or the traditional classes at Prince Georges Community College and University of Maryland. However, we do have data from one group of students at Maryland who had traditional lecture instruction for the first semester and Tutorials for the second semester. The curriculum for these students is listed as TRD-TUT.

A. Overall Results from all schools

The overall survey results for the ten schools are presented in Redish plots in Figures 10-1 and 10-2. In order to simplify the reading of the graphs, we have displayed the results from the three large research universities in one part of the figure and those from the smaller schools in another. The pre-course results are shown with green markers, the post-course results with red markers. A cross shows the result of the expert group.

We make three observations.

1. *The initial state of the students at all the schools tested differs substantially from the expert results*.

The expert group was consistent, with 87% agreeing on which survey responses were desirable for their students. Except for the WP class at DRY, beginning students only agreed with the favorable (expert) responses about 50-65% of the time, a substantial discrepancy. Furthermore, students explicitly supported unfavorable positions about 10-25% of the time.

2. *There are some significant differences in the student populations.*

Three of the student populations have significantly more favorable expectations than the students at University of Maryland (DRY, NWU, & MIN). The students at Drury College (DRY) responded even more favorably than the Physics Olympics Team (79% vs. 68%). However, this is an extremely small class (even for Drury) with a corresponding large uncertainty that is shown to demonstrate what is possible but

Figure 10-1

Figure 10-2. Pre/Post Redish Plots for all schools, average of all items should not be considered typical. In general, coming into the introductory physics sequence the students at the small liberal arts (SLA) schools and at University of Minnesota seem to have more favorable expectations than students at Maryland, Ohio State, and the community college.

3. In all cases, the result of instruction on the overall survey was an increase in unfavorable responses and a decrease in favorable responses (though some changes were not significant). *Thus, instruction produced an average deterioration rather than an improvement of student expectations*.

Three sequences showed a significant decrease in favorable expectations overall. These include TRD instruction at Minnesota and both GPS sequences (MIN & OSU). Note that both GPS sequences had significantly better fractional gains on the Force Concept Inventory (FCI) than the TRD classes. In fact, the GPS sequence at Minnesota was considered by the physics education group there to be a very successful implementation.[10]

The overall survey includes items that represent a variety of characteristics, as discussed in chapter 5. To better understand what is happening in the classes observed, let us consider the initial state and the change of student expectations in our various clusters. The clusters and the associated survey items are discussed in detail in chapter 5.

B. The Independence Cluster

One characteristic of the binary thinker, as reported by Perry and BGCT (discussed in chapter 2), is the view that knowledge comes from an authoritative source, such as an instructor or a text, and it is the authority's responsibility to convey this knowledge to the student. More mature students understand that developing knowledge is a participatory process. Survey items 1, 8, 13, 14, 17, and 27 probe students' views along this dimension. The pre/post results for this cluster are displayed in a Redish plot in Figure 10-3.

Our expert group responded favorably to the survey items is this cluster 93% of the time. On this cluster, students' initial views were favorable in a range from 36% (TYC) to 59% (SKD). For comparison, the POT showed favorable views on these items 81% of the time. Only the students at Drury and Minnesota showed any significant change as a result of instruction. The WP students at Drury and both the TRD and GPS students at Minnesota showed significant decreases in the percentage of favorable responses after one year on instruction. Note that Drury students had exceptionally favorable pre expectations in every dimension and ended with expectations that were still among the most favorable.

Survey items 1 and 14 are particularly illuminating and show the largest gaps between experts and novices.

1. *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.*

14. *Learning physics is a matter of acquiring new knowledge that is specifically located in the laws, principles, and equations given in the textbook and in class.*

The expert group was in 100% agreement that students should disagree with item 1 and in 84% agreement that they should disagree with item 14. Disagreeing with these items represents a rather sophisticated view of learning, but favorable shifts on these items are exactly the sort of changes that indicate the start of a transition between a binary and a more constructivist thinker. The interviews strongly support this view. Students who

Figure 10-3. Pre/Post Redish Plots for all schools, independence cluster disagreed with these items were consistently the most vigorous and active learners.

This cluster of items, and items 1 and 14 in particular, appear to confirm that most students in university physics enter with at least some characteristics of binary learners, agreeing that learning physics is simply a matter of receiving knowledge in contrast to constructing one's own understanding. We would hope that if a university education is to help students develop more sophisticated views of their own learning, that the introductory semester of university physics would begin to move students in the direction of more independence. Unfortunately, this does not appear to have been the case. In the touchstone items of 1 and 14, the only significant improvement was in the WP sequences at DC on item 14 (26% to 43%) and the TUT sequences at UMD (4% to 22%), the GPS sequence at OSU (7% to 13%), and the TRD sequence at MIN (12% to 16%) on item 1. The TRD class at MIN significantly improved on item 1 and significantly deteriorated on item 14.

C. The Coherence Cluster

Most physics faculty feel strongly that students should see physics as a coherent, consistent structure. They feel that a major strength of physics is its ability to describe many complex phenomena with a few simple laws and principles. Students who emphasize science as a collection of facts fail to see or appreciate the integrity of the structure. This lack of a coherent view can cause students many problems, including a failure to notice inconsistencies in their reasoning and an inability to recall information through crosschecks. Survey items 12, 15, 16, 21, and 29 were included to probe student views along this dimension. The pre/post results are shown in Figure 10-4.

Figure 10-4. Pre/Post Redish Plots for all schools, coherence cluster

Our expert group was in agreement as to what responses were desirable on the elements of this cluster 85% of the time. The initial views of students at our ten schools were only favorable between 48% and 58% of the time. Most sequences showed a small deterioration on this cluster, except for DC which improved slightly (57% to 63% favorable responses) and the two GPS sequences at MIN and OSU which deteriorated significantly (56% to 48% and 49% to 39% favorable responses respectively).

Two specific items in this cluster are worthy of an explicit discussion.

> *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.)*
>
> *29. A significant problem in this course is being able to memorize all the information I need to know.*

Item 21 is a touchstone. Coming up with two different answers using two different methods indicates something is seriously wrong with at least one of your solutions and perhaps with your understanding of the physics and how to apply it to problems. Our expert group and POT students feel strongly that students should disagree with item #21 at the 85% level. Initially, only 42-55% of the students responses were favorable for this item, and the only significant change is the decrease in favorable responses in the TUT sequence at UMD (55% to 46%) and both sequences at MIN (53% to 40% for the GPS sequence and 46% to 40% for the TRD sequence). No sequence showed any significant improvement on this item.

D. The Concepts Cluster

The group of items selected for the concepts cluster (items 4, 19, 26, 27, and 32), are intended to probe whether students are viewing physics problems as simply a mathematical manipulation of an equation, or whether they think about the underlying physics concepts. For students who had a high-school physics class dominated by simple "problem solving" (find the right equation, perhaps manipulate it, then calculate a number), we might expect largely unfavorable responses to the items in this cluster. However, we would hope to see substantial improvement in this cluster as the result of even a single college physics course. The pre/post results are shown as a Redish plot in Figures 10-5.

Our experts agree on their responses to the items of this cluster 89% of the time. The initial views of the students at the six schools were favorable between 42% (PGCC) and 57% (SKD) of the time. Only two sequences showed significant improvement on this cluster, the WP sequence at DC (54% to 62% favorable responses) and the TUT sequence at UMD (52% to 60% favorable responses) although two of the other WP schools showed some improvement as well. Both GPS sequences showed deterioration in this cluster although only MIN's was significant (54% to 49%)

Within this cluster, the results on items 4 and 19 are particularly interesting.

4. "Problem solving" in physics basically means matching problems with facts or equations and then substituting values to get a number.

19. The most crucial thing in solving a physics problem is finding the right equation to use.

While these items are similar, they are not identical. Agreeing with item 4 indicates a naive view of physics problems or a lack of experience with complex

Figure 10-5. Pre/Post Redish Plots for all schools, concepts cluster problems. A more experienced student could reject 4 but still agree with 19 because of the phrase “most crucial”. However, one would hope that increased experience with complex physics problems would lead a student to disagree with this item as well. For example, 54% of the POT students gave a favorable response on this item as compared to only 22% of beginning students at UMD. Our personal observations of these students indicate that as expected, the POT students have considerably more experience with complex problem solving than the typical beginning engineering student.

Most of the schools begin with favorable responses on item #4 of 35-58%. Our community college (PGCC) is an anomaly, with only 16% of the students responding favorably on this item. This suggests that the group of students at PGCC may be considerably less sophisticated, at least along this dimension, than the average beginning university student. The shifts on this item for the TUT sequence at UMD and the WP sequences at DC and NWU were favorable and significant (e.g., UMD 46% → 68% favorable, DC 47% → 75% favorable, and NWU 46% → 68%). The other sequences deteriorated with the exception of DRY, which did not change significantly but started with a very high value.

All groups showed a low initial favorable response on item 19 (13% (TYC) to 33% (MSU)) but all showed a significant deterioration after one year of instruction except for MIN-GPS, and CAR-TRD which shifted favorably but not significantly and OSU-GPS which did not change.

E. The Reality Link Cluster

This cluster looks at student beliefs about connections between physics and their personal experience. The four items (items 10, 18, 22, and 25) that compose the reality link cluster do not just probe whether the students believe the laws of physics govern the real world. These items also probe whether students feel that what they learn in their physics course is relevant to their personal real world experiences and vice versa. The pre/post results are shown in a Redish plot in Figure 10-6.

Our expert group of instructors was in almost unanimous agreement (93%) with the favorable response on our reality cluster. Interestingly, the POT students only gave favorable responses at the 64% level. Examining their written comments as well as their responses gives one possible explanation. The POT students saw physics as being associated primarily with interesting and exotic phenomena, such as cosmology, relativity, and particle physics, and they did not see a link between this physics and their personal experiences.

The student groups at our six schools started out with fairly strong favorable responses, ranging from 61% (UMD) to 82% (CAR). Unfortunately, every group (except DRY) showed a deterioration on this measure as a result of instruction, and many of the shifts were substantial (CAR-TRD from 82% to 50%; MIN-TRD from 71% to 59%; MSU-WP from 71% to 44%; SKD-WP (over one semester) from 75% to 56%; and MIN-GPS from 72% to 53%). The WP students at NWU started at 80% favorable responses and ended at 77% favorable, the highest of any student group in this study. I will come back to this point when we discuss the interview results.

Figure 10-6. Pre/Post Redish plots for all schools, reality link cluster

F. The Math Link Cluster

One of the hidden goals of the introductory physics course is to help students develop the ability to use abstract and mathematical reasoning in their study of physics. Experts view mathematical equations as concise summaries of relationships between Figure 10-6. Pre/Post Redish Plots for all schools, reality link cluster physical quantities. Many students fail to these relationships and instead focus on just using the right equation to calculate the answer to a problem.

The survey items probing students' apparent expectations[11] of the role of mathematics are 2, 6, 8, 16, and 20. The pre/post results are shown as a Redish plot in Figures 10-7.

Our expert group is in strong agreement on the favorable answers for this cluster, agreeing at the 92% level. Since high school physics courses tend to be decidedly less mathematical than university physics courses, we were not surprised with the initial response of the students in our test classes, which range from 57% to 71%.

Although these lower expectations may be appropriate for high school students and therefore for beginning university students, one might hope that these attitudes would change towards more favorable ones as a result of a university physics class. Unfortunately, none of the sequences probed show improvement in the favorable/unfavorable ratio and six (CAR-TRD, MIN-TRD, MSU-WP, NWU-WP, MIN-GPS, and OSU-GPS) show a significant and substantial deterioration.

Among the items of the cluster, the results on item 2 are particularly interesting.

> 2. *All I learn from a derivation of a formula is that the formula obtained is valid and that it is OK to use it in problems.*

Figure 10-7. Pre/Post Redish Plots for all schools, math link cluster

From our interviews and informal discussions, we note that many students today have had little or no experience with formal mathematical proof. A few did not understand the meaning of the word “derivation,” mistaking it for “derivative.”[12] This lack of experience can produce a severe gap between the expectations of instructors and students and cause serious confusions for both groups. On item 2, the students at no institution showed favorable responses (disagree) at higher than the 53% level (CAR). At PGCC, only 20% of the students gave a favorable response with item 2 initially. They improved somewhat after the class (to 33%). Two other sequences also improved significantly on this item (DC-WP from 35% to 47% favorable, MIN-TRD from 36-44% favorable), but three sequences deteriorated significantly (CAR-TRD from 53% to 33% favorable, MSU-WP from 42% to 17% favorable, MIN-GPS from 42% to 36%). The improvement at DC implies that the deterioration at MSU may not be associated with the Workshop Physics structure, which tends to emphasize hands-on and laboratory activities over purely abstract and mathematical reasoning.

G. The Effort Cluster

Many physics lecturers will expect students to use whatever resources they have available to make sense of the material. Unfortunately, many students do realize that if they do not see something right away, there are steps they can take that will eventually help them make sense of the topic.

An important aspect of the hidden curriculum is to realize that one's current understanding might be wrong, and that the mistakes one makes can be useful in helping to correct one's errors. This dimension is probed by items 3, 6, 7, 24, and 31 on

Figure 10-8. Pre/Post Redish Plots for all schools, effort cluster the survey. For this cluster, the pre/post results are displayed in a Redish plot in Figure 10-8.

Our experts are in strong agreement on the answers to the items of this cluster, at an 85% level. The initial views of the students at the various institutions begins quite high, ranging from 66% favorable (at OSU) to 88% favorable (at CAR). By the end of the year, the shift is dramatically downward, with three institutions dropping in the favorable percentages by roughly 20% (UMD-both sequences, DC-WP, NWU-WP, MIN-TRD, and OSU-GPS, and PLA) or more (CAR-TRD 39%, MSU-WP 30%, DRY-WP 29%, MIN-GPS 47%). In one sense, this may be interpreted that the students expected to make more of an effort in the course then they actually did, as the shifts were largest on items 3 and 6, but the downward shifts on items 24 and 31 were also substantial.

III. WORKSHOP PHYSICS: SITE VISITS AND INTERVIEWS

During the course of this study I was able to make site visits and interview students at three institutions using Workshop Physics: Dickinson College (DCK) and two of the adopting schools, Nebraska Wesleyan University (NWU) and Drury College (DRY). Note that no survey data is shown for Drury College earlier in this chapter because the unusually small class size of their calculus class (eight students) made for unusual results and large uncertainties. However, the interviews I had with students from both the algebra/trig-based and the calculus-based Workshop physics classes provides another view of an adopting institution. To study their expectations, students were interviewed with either the MPEX Survey protocol or the Open MPEX protocol, both described in Chapter 7.

A. Dickinson College: Pre-course and mid-year

I conducted pre-course, mid-year, and post-sequence interviews with students in the Workshop Physics classes at Dickinson College during the 1994-5 and 1995-96 school years. In the 1994-5 school year, eight students were interviewed at mid-year at the end of the fall semester about a week before finals. The students were asked questions from the MPEX Survey protocol in pairs and some were individually given problem interviews (see chapter 7 for a description of problem interviews) including the two-rock problem. In the 1995-96 school year, pre-course interviews were conducted in the second week of the fall semester and post sequence interviews were conducted a week before finals in the spring semester. In the pre-course interviews, students were again asked questions from the MPEX Survey protocol to validate the survey items at the beginning of instruction. Some additional open-ended questions concerning their views on the nature of physics and mathematics were also asked. In the post-sequence interviews at the end of spring semester, the Open MPEX protocol was used with six students including four who were interviewed previously. The students were all volunteers who were paid a small stipend by Dickinson for participating in the interviews. Note that the student sample was not randomly selected. While I will not go into the interviews in detail there are a few points that should be mentioned.

In the first pre-course MPEX survey results from Dickinson College from the 1994-95 school year, we noticed that their students' pre-course results were substantially more favorable than the other schools participating in the study at that time. In the subsequent years, the survey was given before the course instructors gave their course overviews on the first day of class. The results were unchanged. However, in the pre-course interviews described, most of the Dickinson students were found to be familiar with at least some aspects of the Workshop Physics course either from contact with the physics faculty or discussions with friends who had already taken the course before the first day of class. In addition, other departments now offer classes using the workshop approach including calculus, which is a co-requisite for the Workshop Physics course. I hypothesize that either Dickinson is attracting students with more constructivist expectations or this foreknowledge of how the class is run is affecting the survey results.

Two surprising expectation findings came out from the mid-year interviews. First, in addition to the conceptual difficulties discussed in connection with the two-rock problem in chapter 9, the students were very reluctant to demonstrate their predictions to the two-rock problem mathematically. Instead they wanted to go into the Workshop Physics Classroom and set up an experiment. In light of the dominant role of the laboratory in Workshop Physics, this attitude is understandable and perhaps not even an issue for liberal arts students. But for students in science and engineering majors, this prejudice against using mathematical models for predictions before an experiment is a serious concern.

The second finding was that the majority of students interviewed did not see the need to reflect on or reconsider the course material. These students felt that once they had learned the material through the appropriate activities, they knew it and could move on. In physics, the knowledge and understanding of experts is always under reconsideration as new ways are discovered of looking at things and as experts extend what they know to new areas. This finding suggests further probing into this issue and, perhaps, future work into assessing the knowledge structures students build in introductory courses more directly.

B. Nebraska Wesleyan University: Post-Sequence

Nebraska Wesleyan University completed their second year of implementing Workshop Physics in the spring 1997 semester. As described in Chapter 8, their implementation is unique in that they only teach one flavor of introductory physics, algebra/trig-based and calculus-based in the same class. I made a site visit two weeks before finals in April 1997 where I attended one session each of both Workshop Physics classes and interviewed 10 student volunteers.

During my class observations I noted some similarities and differences with the Dickinson implementation. The room layout was conducive to group activities and class discussion as well as lecture and demonstrations. The students worked in groups of three or four on opposites sides of lab benches aligned parallel to the front of the room. Each group had a computer and a lab set up. The day's lesson was on flux and was very difficult for most of the students. The morning had an additional facilitator, a graduate student who was working part time. Thus, there were two instructors available to help the student groups. In the afternoon when the professor was alone, he used what he had learned from the students in the morning to give them a better, more detailed presentation before the students began the group lab activity. Despite this, several groups had to wait for the instructor to assist them when they got stuck. This is a major difference between the implementation of Workshop Physics at adopting schools and Dickinson College. At Dickinson, they use undergraduate TAs to assist the student groups in the classroom so that there are three facilitators in the classroom at all times. There are ways to address this problem without adding staff, but they require adjustments and fine-tuning over a period of time.

Another difference was that the instructors at NWU had just begun customizing the material this past year to meet the need of their students while Dickinson has been running this curriculum since the late eighties. The instructors at NWU are aware of their current problems and are working to fix them. They will need at least one more iteration of the research and development cycle to make their activity guide and the class better suited for their unique bi-level approach. This is not to say that the course is not doing well, just that there are difficulties that need to be addressed. Part of this evaluation is to help identify less obvious difficulties.

I met with all ten student volunteers separately. Nine of the ten were interviewed using the MPEX Survey protocol. The tenth student was interviewed with the Open MPEX protocol. The results were very intriguing. Note that the analysis presented below is more detailed than for other interviews in this chapter. There are several reasons for this. First, this was the only site visit to a school adopting Workshop Physics that met the study criteria, twenty or more students in a calculus-based class closely following the implementation at Dickinson College in a similar environment. Since Workshop Physics used guided-discovery laboratory as the primary method of instruction, we would expect Workshop Physics to have the largest favorable effect on student expectations. As we saw from the survey, only Dickinson showed any significant improvement in student expectations (in the concepts cluster). However, the WP sequences at DC, NWU, and DRY ended the year with more favorable expectations than the other sequences. Also, DRY and NWY had less deterioration (in units of σ). Second, these were the only MPEX interviews conducted with a good sample from a sizable calculus-based class that used the most current version (version 4.0) of the survey. Third and last, two additional controls were added to address concerns raised in the earlier interviews.

- To prevent the interview itself from unknowingly influencing the student responses, the students completed the survey before starting the interview (No more than 24 hours before)
- This student sample was very representative of the entire class. At least three students were interviewed from the top third, middle third, and bottom third of the class. The students were rated by the instructor based on their overall grade at the time of the interviews.

As the interview transcripts are too long to include in this dissertation, transcript summaries of the interviews (organized by topic) with all nine students interviewed with the MPEX Survey protocol are included in Appendix D. In addition, their interview responses to the survey items listed by item are included in Appendix C. Nine of the ten students interviewed and eight of the nine interviewed with the MPEX Survey protocol were majoring in biology, biochemistry, or biopsychology.

While all the interviews were useful for learning about the students' expectations, the five interviews described below were selected to see what the students' expectations are like at the top and bottom of the class.

1. The view from the top: Charlie, John, & Amy

The results from the three students in the top third of the class were particularly interesting. The three pre-med students, code-named Charlie, John, and Amy, had very different expectations and views of Workshop Physics.[13] All three were very bright, motivated, and very articulate students.

Charlie:

Charlie is a pre-med molecular biology and biochemistry major. He had no prior knowledge of workshop physics or the workshop approach until he showed up in class. In high school, he had math through calculus and five years of science including one year of physics.

During the interview, I found Charlie to have generally very favorable expectations. He is strongly constructivist. This is reflected in his responses to items 1, 14, and 34 from the MPEX survey shown in table 10-5. Note that in all three of his responses he refers to building his own understanding. He recognizes that at least sometimes he needs to step back, reflect, and piece things together himself. He also uses physics to understand the real world and tries to tie the physics he is learning to familiar experiences. He both values derivations and goes over them on his own. He goes over both his homework and exams so that he can understand his mistakes and correct them.

He prefers the Workshop Physics methods to the traditional methods used in his other science courses. That is not say he thought the course was perfect. While his first semester group included his friends who were also well motivated to learn and

Table 10-5a: Interview responses for item 1 from students in the top third of their class at NWU.

Item 1. 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 pay close attention in class.

Favorable Responses

Charlie: *And I disagreed with this one. Uh ... basically because the under- — the big word there that got me was "understand." To understand it, just reading and doing the problems and going to — paying attention in class just feels like going through the motions, to me. To understand it, I think it takes a lot more — critical thinking — going — going back and going over it in your mind and stuff, because you'll have new concepts, I think, and stuff that sometimes just doesn't go over well the first time you see it or consider it. A lot of it just takes rehashing.* [Okay. Now, what do you mean by "critical thinking"?] *... I mean not just memorizing formulas or taking things because they're presented, you know, just to be true; to go a step beyond that and maybe why or how this is — how they can — how come the book can come and say this, or where they get this from. If they give you a reason, try and understand it. I mean you — not just take it as fact. Try and understand why it is.*

Unfavorable Responses

John: *And I put "strongly agree," number five. And ... that's just ... all I really need, usually, for most problems. There're a few that I ... have to ask questions on — although it has happened. But most of the time, I can just read the text. Even if I have to read it over and over, I'll get it eventually.*

Amy: *And I said "strongly agree," because if you were to do all of these things, you're pretty much guaranteed to learn it.*

Table 10-5b: Interview responses for item 14 from students in the top third of their class at NWU.

14. 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.

Favorable

Charlie: *This one I disagreed with. And I think I disagreed with this one because it just sounds like this means that you're just memorizing the — the basics. And — and, again, I like to go beyond that and — and go to the understanding of where it all comes from — where the laws, principles and equations arise from. And so I disagreed with that one.*

Neutral

John: *Three, "neutral." Again, I think it depends on the type of person you are. Learning physics as a whole — really learning physics — is more than just ... principles, equations, laws. It's ... in understanding and incorporating all this. But to pass a course, learning physics, I think that's all you really need to get by. And I think some people maybe aren't interested in it and are — or maybe even aren't capable. It just doesn't — doesn't do it for 'em, and so they don't think that way — which isn't bad. It doesn't mean they're not smart. It just means that that's a different way of thinking ... they don't think about that. So, therefore, I ... just chose "neutral."*

Unfavorable

Amy: *I agree with that. Learning the fundamentals of it — you've got to do that.*

Table 10-5c: Interview responses for item 34 from students in the top third of their class at NWU.

34. Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text.

Favorable

Amy: *I agree. … If you were given a problem to solve ... you definitely need to figure out, you know, "In what area do I need to apply what I know? And what part of that area do I need to pick at most? And what do I need to solve for to get this problem solved?" So, you're constantly picking apart and thinking about what you've learned and what you ... can apply from what you know — along with, you know, of course, sub molecular level you can't, hands-on, say what's going on; but from what — Your creativity, I guess would come into that point as far as being able to restructure what you've learned from … Just the same as the people who would come into a test with photocopied answer sheets from the homework problems. They're not restructuring, rethinking, reevaluating what they've learned. They're trying to get the answers to all the problems and hope there's problems like that on the test that they can, quick, go through and pinpoint something, so they can plug and chug something. That's not rethinking or reanalyzing. Those people won't do well, and they won't get an 'A' out of the class. So you have to do that.*

Neutral

Charlie: *And I was neutral also, because I — there's times when I have to restructure and rethink; there's times when I don't. And it just depends on how clear the material is presented or how well I understand it at the time. Sometimes it just hits me all — real fast and hard, and I just have to — "Woah!" — step back from it for a while and go back later and slowly pick at it ... take it a step at a time.*

Unfavorable

John: *"Disagree." Again, I took that question to mean that you ... have to sit down — I know people who will go through a class — right? Then they'll go back and they'll rewrite out notes on a page, from the textbook, or from the class, or lecture. I don't need to do that. Usually, just when I get in class and what I read out of the book, homework problems I have to do — that's good enough.*

understand the material, his second semester group partners were not as serious. In his words,

> *Because in the first semester, I was with three friends, and the — You know, we were a group of three. So, I was with two other guys. And one of 'em was going on to physical therapy, and the other was going to take MCAT with me. So, it was really important — We knew we had to really learn and understand some material. And we were friends, so we could criticize each other and — and it was just a lot easier to work with than to — We ... just were there for business, it seemed like. Even though we were friends. It sounds like you would be more apt to goof off, but we're all good students and we were serious about why we were there. And we got a lot done. This second semester, I'm with three guys that have — I just met this semester, really. And it's a lot harder, because they're not as serious about it, it doesn't seem like, it seems like we spend a lot more time goofing off or just chatting and get sidetracked. And — And then when it comes to understanding stuff, sometimes they don't seem to be hung up on understanding as much as I am, so that they'd rather just — You know, they're there to get it done, get through the stuff so they can leave. Whereas, it takes me a while longer to get through stuff and to keep up with them, because I want to understand things as I go along.*

Although he was fairly constructivist, he felt that it was not necessary to do experiments to introduce a topic. For example, he felt that in the case of learning that there were two kinds of charge that it was pretty self-explanatory and *that* [it] *just seems like stuff that could be, you know, told you. … I'd just rather go spend more time on more complicated stuff than the real simple.*

<u>John & Amy:</u>

John and Amy were interviewed separately, but they have similar mixed expectations. They are both pre-med biology majors (Amy is actually a biochemistry major) who were both successful with at least one semester of traditional undergraduate physics instruction prior to transferring to NWU from other schools (Iowa State University and University of Nebraska, Lincoln, respectively). Both had heard about the

Workshop Physics course before taking the class, John from last year's students and Amy from the faculty. In high school, John had math through AP Calculus and at least four years of science including two years of physics. Amy did not discuss her high school background in detail but she did not have physics or calculus in high school. However, after her first semester of traditional physics in which she received an A+, Amy considered becoming a physics major. She avoided taking calculus until this year (she did not want to take it).

They both are more transmissionist than constructivist in their view of physics learning and knowledge. For example, their responses to survey items 1, 14, and 34 in Table 10-5 indicate more of an emphasis on problems and equations than in building their own understanding of the material. Although in item 14 John indicates that while it's not necessary for learning physics for the class, understanding is important for really learning physics. And in item 34 Amy states that she is rethinking and restructuring what she is learning and what she knows while she solves problems.

Another indication of their mixed expectations is that while they both believe it's important to see derivations, they don't actually go through them themselves. While John believes it's important to see where equations come from and to see how the concepts link to the equations, he does not believe it's necessary to work out the algebra (*because then it becomes more of a math exercise*) or that derivations are *strongly* useful. Amy thinks *it's necessary to know* [derivations] *and be able to implement them*. However she doesn't go over derivations in the book. This is not surprising since she doesn't read the book much *unless it's to clarify ideas.* (Note that this is not that unusual. Many students taking Workshop Physics at Dickinson use the activity guide as their main text and pretty much ignore the assigned text. In fact for at least one year Dickinson did not use a textbook with the Workshop Physics class.) In class, she thinks it's important to watch the instructor do derivations though she doesn't ponder them. She thinks it's important to watch because *what I get out of ... watching someone derive a derivation or a proof is it gets me closer to being that type of person who'll be able to do it, myself. I'm not, by nature, somebody who does that.* It is interesting to note that the interviews hint that both Amy and John do not like math very much.

They are both in the binary stage[14] at least with regards to physics knowledge. They both tend to see physics knowledge in terms of facts and situations. While both value concepts and understanding, both value the ability to apply equations to new, similar situations more. However, neither Amy nor John values building understanding from experience, both prefer to learn from authority, i.e. the instructor and the text. Also, both believe that the ideas in physics are relevant to other sciences and that science is coherent in that respect, but not that physics itself is a coherent framework of ideas. Amy's link between physics and reality is as strong as Charlie's is and she believes that thinking about the connection is an important part of the course. John's reality link is also strong and he gives several examples of real world situations that use ideas from class. He believes that while the connection between physics and the real world is useful it was not essential for this course. Both of them prefer to learn the material and work out problem solutions on their own.

Not surprisingly, both John and Amy prefer traditional Lecture to workshop physics. John feels that WP might be good for learning the concepts in a course where the concepts are hard but for him this course was mostly review. Although John worked with a “good group” *where I’m telling them things sometimes and they’re telling me things sometimes*, he would have preferred a faster pace to cover more material. John felt that physics had two parts, a basic fundamental part and an applied, complex, interrelated part. Like Charlie, he felt that while discovery learning wasted time on the basics, he thought discovery of complex information and applications was good. This is somewhat reinforced by his need to work in a group to learn physical chemistry which he describes as being *like trying swimming and trying to hold your head up*. Here he found working with a group useful because *together we were able to solve problems we probably wouldn’t have been able to do individually*.

Amy felt that she learns best on her own or one on one with a “knowledged” person such as a professor. She learns when things are explained to her by the book or by a professor. She would rather go off and read the book on her own than do Workshop Physics. However, Amy did not have a pleasant experience in the Workshop Physics course. Amy’s group partners were friends and they tended to exclude her from the group when both partners were present; although, Amy found she was able to learn effectively in Workshop Physics when one of her partners was absent. Based on this and other experiences with group work, she thought working in groups was helpful because no one knows everything and they could share information. However, when it comes to interactive activities, *I think interactive work is appropriate in a research setting, when you already are knowledged, and maybe the two people are learning together, and you know, you have one professor working with you when you're doing research. That, I think, should be group work.*

It is interesting to note that in most traditional lecture classes both Amy and John would be considered ideal students. They have succeeded grade-wise in both the traditional class and the Workshop Physics class. They both learn well on their own. With the exception of their attitude towards derivations, many physics majors including myself have had similar expectations at the end of the introductory physics sequence. So what is the problem? What is wrong is wrong with the picture painted here? Nothing, if they were physics majors. At that point in their academic careers, many physics majors have learned to apply the equations of physics without a good understanding of physics concepts or a good understanding of what physics is (as discussed in chapter 2). It is only later iterations of core courses, preparing for the qualifier, or sometimes after teaching introductory physics, that physics majors develop a good understanding of physics and become more constructivist physicists.

But Amy and John are not physics majors and this is the last physics course they will take. While they are able to recognize physical situations similar to things they have seen before, it is doubtful they could apply the concepts of physics to unfamiliar situations. Their knowledge of physics is not as flexible as Charlie’s. In terms of the Hammer dimensions of constructivism, they believe that knowledge comes from authorities, that physics is weakly coherent in that it applies to other sciences, and that physics knowledge is based on equations and facts rather than concepts. I believe that their expectations of what physics is and how it is done may have prevented them from seeing the benefit of the Workshop Physics approach.

2. The view from the bottom: Hanna & Kim

Now that we have looked at the expectations of students in the top third of the class, it is instructive to look at the expectations of students in the bottom third to try to understand why they are not doing better. The three biology majors, code-named Hanna, Kim, and Roger, had expectations and views of Workshop Physics that provide an interesting contrast to the previous section. All three were having difficulties with the course. Their responses to items 1, 14, and 34 are shown in Table 10-6. Hannah's and Kim's interviews are discussed below. However, because Roger was an older returning student with a very unusual perspective, his interview is not discussed here.

Kim:

Kim is a senior majoring in biology preparing for a career in physical therapy. She is an Afro-American. She was the only minority student I interviewed at NWU and one of the only minority students in the class. She had no prior knowledge of the Workshop Physics course coming into the class. In high school, she had three years of science including one year of physics and mathematics up to pre-calculus including statistics. Like five of the seven students I interviewed at NWU who had high school physics (including Charlie), Kim did not get much out of her high school physics class. In her words, *The only thing I think I might have mastered was friction and the section in dealing with waves.* Unlike most of the other students I have interviewed, Kim has a history of learning problems with mathematics beginning in second grade. However, her problems with mathematics in this course are at least partly due to a lack of use and a lack of conceptual understanding. She took calculus two years ago at NWU but *it*

Table 10-6a: Interview responses for item 1 from students in the lower third of their class at NWU.

Item 1. 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 pay close attention in class.

Favorable

Roger: *"Disagree." And why I said "disagree" is because I know it's just a straightforward science and it hasn't changed in so many years — just different philosophies of the actual premise of physics. But there're so many different angles that one question can take on. If I read the book — and since we have — we can write down anything we want, long as we generate it ourself [sic] and bring it into the test, I could copy that book word for word and take it into the test; but it's not going to help me. Because his question, or your question, or anybody else's question, most likely is not going to match up to anything that's in the text. So, it's more of a — You need more cognitive development than what a test is actually going to give you.*

Neutral

Hannah: *I marked agree. … I mean that covers, like, basically everything I do. I mean when I read this, I thought that covered, like, everything. I don't know what else you could do, besides read the text, work the problems and pay close attention in class. I mean, I guess I shouldn't say — Maybe I should disagree with it, because it's not all. You always have to think about it. You can't just, like, be a robot and do physics. But, mostly, that's...that about covers it. So, I don't know if I should change my answer or not.* [That's something you have to decide.] … Okay. {She changes her answer to disagree}

Unfavorable

Kim: *And I said "agree." … But that doesn't totally answer everything. That's part of what I need to do. So, that's why I picked "agree." I need to spend a lot of time with the teacher. So — but I need to read, work most of the problems and pay close attention.* [What do you need to do with the teacher?] *I have him — after I read, if I have problems with the — the problems. Or if I was trying to pay attention in class and didn't understand, I'd go to my professor for just verification — to see if I'm on the right track.* [Okay.] *Clear up any misunderstandings I have about the homework or the concept that we are doing...*

Table 10-6b: Interview responses for item 14 from students in the lower third of their class at NWU.

14. 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.

Favorable

Hannah: *I think I should disagree with this, because it's more than just acquiring knowledge. You also have to put it all together. It just can't be a bunch of facts.* [Okay. Why'd you initially agree with it?] *Because, well, I don't know. Because I was in an agreeable mood. I mean I think that was the basic part of learning physics, but I guess to understand physics — which is, like, a deeper meaning of learning … you have to be able to, like, put all that stuff together. So, then I disagree.*

Roger: *And I strongly disagreed.* [Why do you strongly disagree with that?] ... *I guess ... it's kind of coming to a sense of — Talking to other people that have taken physics, or — or hearing people in class, well, some people are getting it and some aren't. And some have stronger backgrounds than others. So, it's like, "Okay. Why is he getting it?" and I might not be. And why is this cluster not getting it? And, okay, they might 've taken this, this and this — which then is allowing them to manipulate the formulas better than this group. That's why this — Even in the book — Even in the books, they don't actually say, "Okay, do this, and then next do this, and then do this. It's like saying, "Do this, this, and here you go." There's a — lot of — And even in teaching it, in — And that — My teacher's way — it's just, you know, a lot, in general, of ... taking for granted what — I'm losing my ... thought.* [What students are able to do.] *Yeah. Yeah, you know, it's like, "Okay. Here's the formula. Here's the end product. And you do this, this and this and this; but there's no "why" — why's and how's — to get to this. Or a lot of people, sometimes they'll go, "Okay, I get it to here, and you've lost me here." And that's probably a ... mistake for many of us in not going, "Okay. Why? Show me this part."* [So, it's ... not just the laws, principles and equations; but a lot of it has to do with the how and the why.] *Um-hmm*. [And based on your observations, you feel this depends a lot on what you bring into this class from the — from what classes you've had previously in your background.] *Right.*

Neutral — No neutral responses

Unfavorable

Kim: (Kim sounds like she is on the verge of a shift here.) *I put "agree," and I think that ... Well, all things that we learn are the concepts, the laws and the principles and the equation — I guess it's a matter of how you acquire that knowledge. … Okay. The way I'm taking the question would be is that physics is more than just memorizing the laws, principles and equations. To me, it's about how you learn. I'm not making sense. I agree with that statement – that it's a matter of understanding the laws, principles and equations; but I think it's all in how you learn it.*

Table 10-6c: Interview responses for item 34 from students in the lower third of their class at NWU.

34. Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text.

Favorable

Kim: *And I put "agree." Ahem. Um ... Like, you can — with this, I took it to mean with all the different concepts we learn — they combine concepts together. And so you need to be able to take one concept and add it to another and make it all tie in together. So, that's why I chose "agree."*

Roger: *I said "strongly agree." And the reason why I say that is just the way it's ... taught — is that to make it sink in to any of the individuals here, we're restructuring and rethinking and formulating it ... into the way our mind set learns. And I think that's what I was thinking about, too.*

Neutral

Hannah: *I said "neutral," because ... it does require that I substantially rethink — it's — I don't know what "restructure" really means, but "reorganize" ... But the "substantial" part — I don't know what — to what degree. I'm not sure. That's why I put "neutral" — because I find out that, like, it does require that. I wouldn't say "disagree." … But I'm just not — I put "neutral," 'cause I wasn't really sure to, like, what extent they actually mean.*

Unfavorable — No unfavorable responses

hasn't helped me in this course because I don't remember half of the stuff I learned sophomore year. I haven't used it. I know what it is, but I can't explain it.

Kim has some favorable expectations for learning physics. She values building her own understanding and has some sense of physics as a coherent structure. She understands that different people can come up with different ways of looking at concepts or problem solving and that this is a creative process. She understands that looking at things from different points of view is helpful. As shown in Table 10-6, she is mixed in independence with indications of reliance on the professor to explain things in office hours.

She believes that physics is strongly connected to the real world and that this connection is strongly emphasized. However, she does not connect her real world experiences to the physics she is studying.

She strongly favors concepts over equations, but her math skills are very weak and this seems to be affecting her problem solving on exams and homework. In her words,

> *I said earlier sometimes I have a problem with tying in the concept with the math part of it. I think the concepts will tell me how it works or why it works this way, but sometimes I just have a problem tying in the math to give the mathematical answer. But I can look at the problem and see why and how the concept will work.*

She is an example of a student who sees problem solving and conceptual understanding as separate. For example, when asked about which activities were most useful for learning physics, she replied,

> *Just to learn physics or pass a test?* [To learn physics?] *... the things we do in class — the hands-on type of activities we do. To me, if you want me to learn physics, I think it'd be more understanding the*

> *concepts than to plug in the math. Because physics is more than math. Physics is more than can you fill in the equation. Well, what good is it if I don't understand what it means? So, I think learning the concepts — which is what we do in class — more so than the math part — helps me to learn the physics. But on the test, it's more math problems than it is telling concepts.* [So, what do you find most helpful preparing for the exams?] *Working the homework problems.* [Okay. Now, of all the things that you do, which would you say were least helpful for helping you learn physics?] *None of it is ... I want to rephrase that. All of it is good to have. I can't say, "Throw out the homework," or, "Throw out the" … But it just — It just depends on where you ... 'Cause the homework is good for the tests, but the concepts are good for just understanding — the understanding of physics. … Both of them are good.*

She reminds me of several students I have worked with in algebra/trigonometry-based introductory courses who have an intuitive feel for the concepts of physics but have difficulty connecting the math to the concepts to do the homework problems. However, even in problem solving she is moving towards the expert view. When addressing one of the survey items dealing with problem solving, she replied,

> *I was thinking more in terms of understanding the problem. Anybody can work a problem just plugging in numbers. But for me, when it comes to problem solving, I — sometimes I can't even draw the picture; so, it's more than just — for me, it's more than just plugging in the numbers. It's being able to understand where to start and how to even get to the right principle.*

And later when asked whether finding the right equation is the crucial step in problem solving,

> *I put "agree," but I would — For me, I think I have ... to change it. Sometimes, the most crucial thing for me is setting it up, setting up the picture. … For me, knowing what factors are in this picture to come up with the right equation. That's what I worry about.*

She tries to make a qualitative representation to understand the problem, a characteristic of expert problem solvers discussed in chapter 2. Even here, she sometimes had problems,

> *Well, sometimes when you get ready to set up a problem, you can always draw pictures first, so you can see what you're working with. And sometimes I don't know where to start. I don't know how to draw a picture — the diagram — that goes with the problem. So, that's one of my biggest problems — being able to visualize it.*

She values derivations and spends a lot of time on them. However, she seemed to be confusing a derivation with a derivative and her idea of spending time on them was to ask the professor about them. Also, she looks at example problems in the textbook similar to the homework problems but she doesn't try to figure them out herself. However, she does try hard to work on homework problems alone even when she gets stuck. She meets with a group before homework is due to compare answers and also meets with them to prepare for exams.

When asked if learning physics in the Workshop Physics style would be an advantage to her in physical therapy school or in her later career, she responded,

> *Oh definitely. From this class, I've learned more than just physics. I've learned how to ask questions, how to try to come up with a method of solving problems — those types of things — critical thinking skills. Those types of things I get from this course. And then physics as a — the topic — you can use it in the real world as well. I learned to move things with physics.*

She seems to appreciate Workshop Physics although she doesn't like physics because she finds it very difficult. When asked what changes she would like to see in the course, she answered,

> *Um ... I think maybe in the what part of lecture we do have in class, maybe working more on math — tying in the math part with the*

> *concepts. Not just coming up with an equation; but actually applying the equation to the problem in class, to have examples. We go over our homeworks sometimes, but I think I would put more math, actually tying the concept and the math together — besides just coming up — we do a lot of coming up with the equations, but we don't really use the equation to the homework outside of the class.*

Basically, this is a request for the instructor to model problem solving for her and perhaps for additional instruction to help her improve her problem solving skills.

Students like Kim with a weak understanding of math are unfortunately very common in algebra/trig-based and calculus-based introductory classes. They construct a qualitative understanding of physics that is not reflected in the homework and exams. They are often frustrated in traditional lecture classes and just do whatever is necessary to get a decent grade. I can’t determine from our interview if Kim is learning more in the Workshop Physics format, but she has developed more positive attitudes towards physics and the class.

<u>Hannah:</u>

Hannah is a junior pre-med Biology major. She was on the forensics team in high school and now competes at NWU. She had four years of high school science including one year of physics and high school mathematics through calculus. When asked about her high school physics class, she replied,

> *I didn't get very much out of it. It was kind of...There were only, like, six students; and it was, like, all boys. And they were just playing with, like, remote-control cars and stuff. And they wouldn't let me (laughing) play with them, so I didn't — I don't know — I don't feel like I got very much out of the physics class.*

Hannah filled out the survey in 10 minutes the day before the interview. As she was going through her answers in the interview she changed several of her responses.

On these items, she did not seem to have really thought about her answers. When asked about this, she responded that she was bitter about physics when she filled out the MPEX survey for reasons described below.

In her interview responses, her expectations seem very mixed but much closer to novice views than John or Amy. She shows indications of being in the binary stage; she was very concerned about giving the right responses during the interview. However, she is at least somewhat constructivist. Although she initially answered items 1 and 14 with unfavorable responses, she changed her mind while explaining her answers for both items, as shown in Table 10-6. She weakly indicates on some items that you need to take responsibility for constructing her own understanding, yet her emphasis seems to be on understanding what she is given by authority. Indeed, she seems to have trouble putting things together for herself. Surprisingly, she does not expect to intuitively understand anything. Some things she intuitively understands and some she doesn't. She doesn't seem to recognize that she can build an intuitive understanding of physics. This sounds very much like Belenky *et al.*'s description of one aspect of the binary state.[15]

> These women either get an idea right away or they do not get it at all. They don't really try to *understand* the idea. They have no notion, really, of understanding as a process taking place over time and demanding the exercise of reason. They do not evaluate the idea. They collect facts, but do not develop opinions.

Hannah is more focused on equations than concepts, yet she knows she needs more than just the equations. She recognizes that she is seeing the same math and situations again and again but doesn't recognize the conceptual framework. However, she does know that two approaches to the same problem should give the same answer. She believes derivations are important but only goes over them herself before exams. Also, while she feels that physics is strongly connected to the real world and that this is an important aspect of the class, she was not able to give specific examples.

She seems to have three main problems that are keeping her from doing better in the course. One, she recognizes that she doesn't spend enough time studying for this class and going over the class lab activities (only two hours per week). As her study habits show, she crams for the exams (five hours of preparation for an exam). Second, her group this semester is ineffective in part because of clashing goals and bad teamwork. Like Charlie, Hannah had a much better relationship with her group last semester when the students were allowed to form their own groups. She implies that this semester one of her group partners is rushing the pace so that the group is going too fast for her to understand what is going on. Third, the group has had trouble getting timely help from a facilitator in class. They have had many difficulties with the activity guide materials and the lab equipment this semester. They spent a lot of time floundering, waiting for the help they needed. Often, the group would get *hung up on something, like, really small that doesn't even matter but it takes a lot of time.* This issue had become a problem only in the weeks preceding the interview. This was one source of her frustration because she felt that at a private school like NWU she should have better access to the instructor during class. Because of the latter two difficulties, she goes through the activities but she still doesn't understand the concepts. This is another source of frustration for her because she cannot figure things out for herself as she claims she was able to do earlier in the class. In describing her biggest difficulty with the course, she said, *I think just staying focused on the material, probably. 'Cause I mean it's hard — I often — like, rarely do I go home and study it after class, you know? Because I just — I just get so frustrated with it. It just is so ... I don't know. It's just, like, really hard to stay focused in the class. There's just — So much is going on...there needs to be more organization or something. And I should probably — I should. I know I should go home and, like, study it on my own, and stuff like that. But I don't. And that's — that's probably my greatest — like, the reason why I'm not doing as well as I could be. … I don't study on my own enough.*

Another issue was how she felt when the class challenged her common sense beliefs on how things work. In her words,

Just seems like everything is backwards from what I thought. Most stuff. [Is that discouraging?] *Yeah, in some ways. I don't know. It depends, like, how it's presented. You know, if it's presented in a way that I just, like, feel real stupid, then it's discouraging. But if it's, like — If I figure it out myself, it's not so discouraging at all.* [What happens when it's in class?] *Um ...it depends on the day. … Like I said before, like, at the beginning of the semester, I was, like, beginning to figure stuff out for myself, you know. But now, it just seems like mostly* [the instructor] *gets disgusted and ends up writing it on the chapter* [sic] *and so, like, I know he doesn't like to do that, and so, I mean in that way, it's — It's just like I don't even have a chance to open my eyes... . I don't know. It's just hard.*

It was this combination of factors that led to the bitterness mentioned previously.

In addition to learning how to solve physics problems she also learned,

… A lot of interpersonal interaction skills and, like, how to ask questions, and how to work in a group ... [What would you say was the main skill you learned, if any?] *... (laughter) ... The main skill ... I would say to understand physics more than just to solve physics problems. Just to understand it in a deeper way.*

But a little later when she was asked if the main skill she got out of the course was to learn how to reason logically, she replied,

I said, "agree," ... I get other skills as well. But this would probably be the main skill that I get out of it ... I hope it's what I get out of the course. I don't know. I mean that's the main skill I want to get out of

> *the course, but I don't know if it's the main skill that I have gotten out of the course.*

And when asked if learning physics with this method would give her an advantage over other pre-med students, she said,

> *I don't know. … I mean I can see some advantages to it, but also I think in other physics classes they have, like, just one lab and stuff like that. So, they still get hands-on experience; but maybe they're learning the concepts, like, in a more solid way. … You know, like more concretely presented, instead of, like ... instead of just kind of, like, figuring it out. You know, they're just given, like, "Learn this".. and so they may really, really learn it — instead of just kind of like, "Play around with these cars and see what happens when they, like, crash." And then in three days, we'll, like, figure out what it means.*

Hannah had the background to do well in this type of class. But her expectations, her study habits, and problems with the class implementation all contributed to her getting less out of this class than she might have.

C. Drury College: Post Sequence

At Drury College, I observed both the algebra/trig-based and the calculus-based Workshop Physics classes and interviewed twelve student volunteers, four of them from the calculus-based sequence. The calculus-based class was very small, only 7 students, but it is worth discussing this class briefly because this sequence had the second best improvement in FCI fractional gain and the most favorable expectations of all the classes in the study.

The interviews confirmed that the students have favorable expectations, but it is interesting to note some of the differences between the WP classes at NWU and Drury. The contrast was quite noticeable because I went to NWU immediately after my site visit to Drury. The Drury students were more constructivist and less mixed in their expectations than the NWU students. Like the NWU students, the Drury students also had very favorable responses to the reality link questions, but they were better at seeing how understanding physics would be useful to them in their life and in their careers. Also, the Drury students seemed more satisfied with both their groups and the Workshop Physics curriculum. I will come back to this point in the next section.

IV. DISCUSSION

A. MPEX Survey

In this chapter we have discussed the use of the MPEX survey to measure student cognitive attitudes in physics. We gave the survey in classes at ten schools that had varying entrance selectivity and that used either traditional instruction or one of three research-based teaching methods. We find explicit answers to the research questions we posed in the introduction.

> *Q1. How does the initial state of students in university physics differ from the views of experts?*

At the ten schools tested, the initial state of students deviated significantly from that of the expert calibration group with overall responses ranging from 50-60% favorable. The results on the reality link cluster (60-80%) and the effort cluster (65-90%) were much closer to the expert response than the overall results and the results from the other clusters.

> *Q2. To what extent does the initial state of a class vary from institution to institution?*

The student attitudes at UMD, PGCC, MSU, and OSU as measured by the survey were very similar. The attitudes of beginning students at MIN and the liberal arts institutions (DC, CAR, DRY, NWU, & SKD) were more favorable in two to five of the measured dimensions. The beginning students at MIN, NWU, and DRY also had more favorable attitudes on the overall survey.

Q3. How are the expectations of a class changed as the result of one year of instruction in various learning environments?

At every school but one in this study (DC was the exception), the overall results deteriorated as the result of after instruction. Many of the schools showed significant deterioration on two important clusters: half on the math link (with the others showing some deterioration) and half on the reality link (with all but one of the others showing some deterioration. Also, the expectations of students taught with the GPS curricula were not better and in some cases were worse than the traditional classes at CAR and MIN.

B. MPEX Interviews

Interpreting the analysis of the MPEX interviews produced some interesting results both in terms of the students' expectations and in terms of our understanding of the implementation of the Workshop Physics curriculum. In this section, interview responses from all nine NWU students are discussed. Leb, Krystal, and Ramsey were in the middle third of the class.

1. Expectation issues

In general, unlike the students in Hammer's dissertation study who were either constructivist or transmissionist (see chapter 2),[16] the NWU students I interviewed had mixed expectations. Some of the students like Amy and John were not prevented from succeeding in the class by their transmissionist expectations. But their expectations did seem to prevent them from getting the full benefit of the Workshop method. In addition to the individual student expectations described above, there were also some general findings that I would like to point out.

As we saw earlier in the chapter, most classes (including the Workshop Physics classes at Dickinson College) show a decrease in the number of favorable responses in the reality link cluster over the year of introductory physics,. At NWU, the students began and ended the sequence with more favorable responses in the reality cluster than most of the schools in this study, even Dickinson College (see the Redish Plot in Figure 10-6). The NWU students went from 81% favorable to 77% favorable on the reality link cluster over one year. For comparison, the DC students went from 72% to 68% favorable (combined std. error = 5%). Although they both change by the same amount, the NWU students start and end more favorable than the Dickinson students.

This extremely favorable response from the NWU students is reflected in the interviews. Almost all the students I interviewed at NWU believed that the physics they learned in the classroom was strongly connected to the real world. In fact, all the students interviewed in the upper two-thirds of the class gave explicit examples of how they were connecting physics to their own out-of-class experiences. Part of the reason for the favorable response on the reality link cluster is due to the way many of the students look at learning and part is undoubtedly due to Workshop Physic's heavy emphasis on laboratory activities. But part of the favorable response is due to the instructor connecting what the students are learning to everyday experience. In Kim's words, *I think every problem we have in class, every example he's [the instructor's] used he's related to a real world concept. It's not anything that we've never heard of before. … We use real life examples everyday.*

There are two items on the survey, items 17 and 33, that deal directly with students' perception of physics and the class. They read as follows:

17. Only very few specially qualified people are capable of really understanding physics.

33. It is possible to pass this course (get a "C" or better) without understanding physics very well.

Both of these items can reveal a lot about students views on the class itself. The NWU students' responses are shown in Table 10-7. Item 17 often reveals whether or not students believe they could have learned and understood physics in this course. This question was asked in eight of the ten interviews including John, Amy, Hanna, Kim, and Hanna. Everyone except John and Krystal felt that anyone is capable of learning physics; although, some of them did add conditions such as if you apply yourself (2 students), or if you really want to (2 students). John, on the other hand, responded neutral to the question because he felt that there are some people who just can't learn to really understand physics no matter how hard they try. Krystal responded that many people can really understand physics, but *you have to have some intelligence*. This result indicates that even though some of these students are struggling, they believe that

Table 10-7a: Responses for MPEX survey item 17 from all NWU students interviewed.

17. Only very few specially qualified people are capable of really understanding physics.

Favorable

Amy: *I strongly disagree with that. I think — I think if you take the time and you concentrate on it, you can learn it. So, I — I never — When I first started taking it that first semester, I never thought I was going to learn it. First of all, "What is this stuff?" — you know. But I — That's why I spent a lot of time on it.*

Kim: *I put I disagree. And I think it depends on the level of physics. Some — I'm taking a course. I understand some things, so I can say I'm capable of understanding. But some of the more technical or mathematical things that I'm not — that I don't grasp, some people do have an understanding of it. But I think, on a college level or a high school level, the materials that they — they teach are — people are capable of grasping some of those concepts.*

Hannah: *I said disagree. I think a lot of people can understand physics if they want to try and put the time into it.*

Leb: *I said "strongly ... disagree." I think if you apply yourself, you can do just about anything you want.* [That works for you, or anyone?] *It works for anyone.*

Ramsey: *I said I disagreed. "Contrary to popular folk lore."* [Can you elaborate a little more on that?] *Yeah. Now, I'm almost rethinking that because of the number of physics majors here. I think that there's very few. I think that most people in our course — I would say that most people understand it. But I mean to what degree. "Really understand" it — I don't know what that means. I guess it ... I think most of the people in our course — and I know I do — I get a lot of course understanding about the physical world around us. I don't know if I really, really understand it like I could teach it. That's what I would assume that means. "Really understand." Then I would say maybe "only a few specially qualified people would." But I don't know. Is that what you mean by 'really understanding' it? Like being able to tell somebody else? Or, is this my interpretation?* [It's your interpretation.] *I'm going to — But it's not like an elite club of people who understand physics. I'll stick with my answer. But I don't...it sounds so limiting ... Let me think. I don't know how I can elaborate, sticking to my answer. But I want to stick with my answer. "Only a few, specially qualified people are capable of really understanding physics ... " I think, for the most part, most of the students in this course understand it to a degree above average. I'll say that.* [All right. And for that reason, you disagree.] *For that reason, I disagree.*

Table 10-7a (continued): Responses for MPEX survey item 17 from all NWU students interviewed.

Neutral

John: *Now, in retrospect to my previous answer, I'd still put "neutral," because I feel that the term "very few," to me, makes it sound kind of elitist in that question. Maybe I'm reading too much into it. But I think there are many people who can understand it. There's a matter of will involved. And then, indeed, there are people who can't; and that's why I put three. No matter how hard they try, they're just not going to get it. And there're some things that no matter how hard I try, I don't get, either. Like art. (laughter) I'm just not into art. And ... But I think that there's certainly a desire factor.*

Krystal: (UNINTELLIGIBLE) *neutral. I wouldn't understand it, but I think — You know, I don't completely understand it. But I think that a lot of people can. You don't have to be special to understand physics. I think you have to have some intelligence, though. That's for sure.*

Roger: *I was neutral on that. And the reason why I put "neutral" is pretty much ... If there's a will, there's a way. If you put your mind to do it, you can do anything you want it to do. And it's ... Anybody can learn it ... I think. It's just that it's what your research is about. It's how it's taught to the individual. If it's laid out in a very simple, straightforward manner, where they're actually looking for knowledge and the cognitive development of the student, versus getting through a textbook, the student can learn it.*

Unfavorable — No unfavorable responses

Table 10-7b: Responses from all NWU interviews for MPEX Survey item 33

33. It is possible to pass this course (get a “C” or better) without understanding physics very well.

Favorable

Charlie: *And I disagreed basically because I think, since we get use our activity guide and you’ve got all the information there that you, you got to understand it and not just because — you don't need to memorize it because you’ve got it all there. So, to do well, you've got to understand it.*

Leb: *And I said, "disagree." You can get a 'C' or better without really understanding all the physics we've been through, but I think you definitely have to learn a substantial amount if you don't know any physics coming into it, to do reasonably well in this class.*

Krystal: *I disagreed. I mean you definitely have to have a little bit of an idea to get better than a "C".*

Neutral — No Neutral Responses

Unfavorable

John: *I put "agree." I guess. You can ... be a plug-and-chug. You know what you need to do in a given situation and just deal with it and pass.*

Hannah: *I said disagree, but I don't know — I might want to change my answer. I think you could pass it without understanding physics very well, if you could just — if you were a person who could just, like, plug and chug and figure out what goes in what formula. I think you could get a 'C' in the class.* [So, what would you change your answer to?] *I would change it to agree*. [So, you're saying — Not just any plug and chugger — you have to be a really good plug and chugger.] *Yeah, but you wouldn't have to understand physics, necessarily*. [Okay. So a good plug and chugger could go far.] *Yeah.*

Ramsey: *And I said four for "agree." I said, "It could be done if someone really wanted to memorize the appropriate material and not be able to apply much of what they know." I would say that someone could get by with a 'C' or better without understanding, because I would say — I would define 'understanding' it by being able to tell someone else what you know — relate to someone else what you learned. And those people who can — I'm sure someone could do a 'C' or better if they memorized what they needed for a test and forgot it in a few hours or something like that. Because I know people do that.*

Roger: I'd agree. … [Well, why ... do you say that?] ... *I mean there's many people I've talked to that ... have gotten a 'C' in the class, and they don't understand it.*

most people can learn physics with understanding. This result from the interviews is close to the results from the survey. The NWU students started even with the Dickinson students at 88%. While the DC students only dropped to 78% favorable (DC had the largest favorable response to item 17), the NWU students dropped to 65%.

Agreeing with item 33 indicates that understanding physics is not required to succeed in the class and implies that understanding physics is part of the hidden curriculum. This question was asked of seven of the ten students including John, Charlie, and Hanna. Three of them (including Charlie) disagreed with this item. But John, Hannah, and Ramsey believed that despite the heavy course emphasis on conceptual understanding in Workshop Physics, it was still possible to pass this class by memorizing, plugging equations into problems, and chugging away for an answer. In other words, by the same means that students use to pass a traditional lecture course when they don't understand the course or when they are trying to get the best grade possible with the least amount of effort. This may be an indication that the homework and the exams may not be adequately reinforcing the goal of understanding physics, i.e. that the problems may not be designed to encourage students to explicitly use their understanding of physics to do well.

Only two of the four students in the top third of the class (including Charlie) and three of the ten students overall preferred Workshop physics over traditional lecture instruction. However, six of the other students including Amy and John believed that learning by lecture was or would be more effective for them than figuring things out for themselves. In the case of Amy and John this was due to their misconception on what they were supposed to be learning, although John did believe that Workshop Physics was a better way to learn concepts. The other four students preferred lectures, either because they wanted things explained to them or because they wanted more recipe-like activities.

Most of these students had at least some constructivist expectations, but these are what we call “apparent” constructivist expectations. Most of these students believe they should be constructing their own understanding, yet deep down they feel that being told is more effective. One reason for this is that working on something when you don’t know what is right or what you are supposed to be learning is uncomfortable for many students. Three of the students including Hannah commented that sometimes they felt they were not learning the right things or they did not know the right answers to their classroom lab activities.

Another reason why students might feel uncomfortable is that Workshop Physics requires a different type of learning from what they are used to in traditional instruction. Two of the students from the middle third of the class, Ramsey and Krystal both commented on this. When asked if the class was what he had expected it to be, Ramsey replied,

> *There's a lot more emphasis on using your hands in lab. I was ready to take notes and study for exams like every other class. So, this has required me to study in a different way. But I don't really have anything to compare it to. But I don't — I like learning like this. It's not too bad. It's just a different way to study, different way of learning.*

When asked how studying for this class was different, he continued,

> *In several of the courses I've taken here, you sat in your lectures for 50 minutes, take notes, review your notes, and basically memorize things for a test. And it might just be — This is the only physics class I've taken, too. It might be that, but that's a different, too ... just having to work all the problems. But the lab manual that we work out of — you*

just keep up by doing exercises every day in lab. You don't really take notes. And sometimes I don't really learn the right thing, because we don't review. A lot of time, we don't go over the material — like in other classes, you have reviews or recitations, I guess, where you can ask questions and those are kind of skipped over here.

Krystal made a similar comment when asked about what changes she would make to improve the class,

Oh, I would add a lecture, somehow, and cut back on the amount of lab time. And I understand what they're trying to get at with the computer workshop, but I — I just — Again, I think it's important. Maybe if they could just kind of just wean us into it, because just — boom — all of that at once, when you're used to that learning style, of lecture, questions, test; lecture, questions, test; and then three hours of lab, you know — like most of us has — the way the programs — the classes are set up here. But I — I mean I wouldn't want to get away from what they're trying to do, so maybe if they could just take one hour out of our week, lecture, and get rid of an hour of lab. Does that make sense?

And when asked which format she would prefer is she had the opportunity to do the class over again, she answered,

Well, I definitely would prefer the traditional, because I'm not one to accept a lot of change — especially thrown at you that fast. And because I learn that way. That's just ... I mean I think I would have done a million times better than how I'm doing right now, had it been not that format. And I am one of those people — I'm really concerned about what I get. My grades are really) important, if I want to reach my career goal

An important result from these interviews is that success in the class, expectations, and mathematical ability seem to describe three different aspects of student achievement. Of the four students I interviewed in the top third of the class, two seemed to be in the binary stage and two had weak math backgrounds.

One of the key aspects of science-education reform and research-based physics curricula is the establishment of a community of learners where the students discuss the central ideas of the course with one another both in and out of class. Although some of the students at NWU discuss their solutions with one another and help one another prepare for exams, they do not discuss or reflect on what they do in class when they are out of class. This is in contrast to Dickinson College and Drury College where the workshop physics students regularly discuss the class activities outside of class in the same way the NWU students discuss their homework.

Almost all the students I interviewed at Drury worked with other students outside of class at least once a week. They discussed all aspects of the class, not just the homework assignments and the exams. In addition, when asked about the advantages of taking workshop physics, many of the students answered as Charlie did, that this way of learning physics was helping them learn useful knowledge and skills that they could apply beyond the class. While some of the NWU students were able to see connections between the physics they were learning and their careers, the Drury students saw the connection more clearly and were able to cite specific examples.

In general, the implementation at Drury seemed more successful than the implementation at NWU. The groups functioned better and the instructors seemed to have learned how to manage the class more effectively. However, part of the success at Drury may be due to the nature of the institutions. It should be noted that many of the students in the WP classes at Drury knew each other from other classes and they were encouraged to form study groups for many of their classes.

2. Implementation issues:

Two factors essential to the success of any curriculum that uses cooperative groups are how well the group members work together and whether the group's main goal is completing the activity or trying to really understand what is going on in the activity. Six of the ten interviewed students including Charlie, Amy, Krystal and Hannah mentioned problems with their groups.

In Amy's case, the problem was the way the group worked together. The two other members of her group knew each other outside of class and excluded her when they were both present. However, in the weeks before the interview, one of the other women had been absent and Amy was able to collaborate with her remaining lab partner. Amy said that lab had been a much better experience with just the two of them.

In the case of Charlie, Krystal, and Hannah, the problem was one of conflicting goals. Their goal of trying to make sense of their lab activities was thwarted by some of their group members who stressed getting through the assignment as quickly ("efficiently") as possible. These students were like the poor students in the studies by Chi *et al*.[17] and Ferguson-Hessler and de Jong[18] (see the discussion on the use of example problems and readings in chapter 2) who looked through the material without thinking about it and checking to see that they understood it.

In cooperative group activities, the instructor can counter this tendency by asking semi-Socratic questions of the groups and/or the class as a whole. However, problems with the group dynamics should not be taken lightly. It is an indication that the students' goals for learning do not match those of the instructor or the curriculum. In addition, there were also indications in the interviews that some students were not connecting the classroom activities to the homework and the exams. One student noted explicitly in their interview that they used their textbook to do the homework and the class activities to understand the concepts.

Several of the NWU students interviewed commented about wasted time due to the confusion at the beginning of the period. In Charlie's words,

> *… so there was a lot of confusion time, just setting things up. It wasn't explained well. And that's the big thing, I think. He [The instructor] goes through each group individually and explains how to set something up. But a — rather than doing it as a whole. … I just thought with* [the second semester instructor], *we seem to waste a lot more time, because you couldn't really progress with the lab until you had it set up right. There just was a lag time.*

The students need to have a good idea of what they are doing when they begin the lab activity. Leaving student groups floundering for long periods of time can result in the students being frustrated. This is where having more than one facilitator for 25 students can make a big difference.

From the interviews, we learn that the group dynamics affect how the students viewed the curriculum. When students feel their group works well, they tend to feel Workshop Physics is effective. If the group has difficulties, students tend to believe they would learn more in traditional instruction.

The primary role of the facilitator in all three of our research-based curricula is to keep the group members exchanging ideas and on task. In all three of these curricula, it is essential for the facilitators not to explain the material to the students, but to try to help the students find their own answers. At the same time, the instructors need to monitor the student groups. Several of the interviewed students, including Charlie, Amy, and Hannah, mentioned problems with the groups. The instructor/facilitator also needs to be aware of the dynamics in each group so that problems such as Amy described get resolved early in the semester. However, an instructor needs to be careful not to act prematurely; some groups need a little time to pull together. One option with assigned groups[19] is to change the groups every 3-4 weeks so that a person in a dysfunctional group is not stuck for very long.

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1 D. Hammer, "Two approaches to learning physics," *Phys. Teach.* **27** (9) 664-670 (1989); S. Tobias, *They're Not Dumb, They're Different: Stalking the Second Tier* (Research Corporation, 1990).

2 W. F. Perry, *Forms of Intellectual and Ethical Development in the College Years* (Holt, Rinehart, & Wilson, NY, 1970).

3 M. F. Belenky, B. M. Clinchy, N. R. Goldberger, and J. M. Tarule, *Women's Ways of Knowing* (Basic Books, New York, 1986).

4 E.F. Redish, J.M. Saul, and R.N. Steinberg, "Student expectations in introductory physics," *Am. J. Phys*. **66** (3), 212-224 (1998).

5 R. Likert, "A technique of the measurement of attitudes," *Archives of Psychology*, No. 140.

6 On items 7, 9, and 34, a majority of our expert group's agreed with a particular position, but one-third to one-fourth of them chose neutral.

7 D. M. Hammer, *Defying Common Sense: Epistemological Beliefs in an Introductory Physics Course*, Ph.D. Dissertation, University of California at Berkeley, (1991, unpublished).

8 Matched data includes only the results from students who completed the survey both at the beginning and at the end of the period in question.

9 With one exception, the data presented for Carroll College includes students who took the MPEX survey and the beginning and end of the two semester sequence.

10 Private communication with Tom Foster and Laura McCullough from the Physics Education Group at University of Minnesota (Fall 1997).

11 See Ref. 5-20.

12 This led us to include the phrase "or proof" in item 2.

[13] The interview code-names correctly reflect the gender of the students.

[14] See Refs. 2 & 3.

[15] See the description of cognitive beliefs of adult learners in Chapter 2 and Refs. 2 & 3.

[16] See Ref. 7.

[17] M.T.H. Chi, M. Bassok, M.W. Lewis, P. Reimann, and R. Glaser, "Self explanations: How students study and use examples in learning to solve problems," *Cog. Sci*. **13**, 145-182 (1989).

[18] M.G.M. Fergusson-Hessler and T. de Jong, "Studying physics texts: Differences in study processes between good and poor performers," *Cognition and Instruction* **7**, 41-54 (1990).

[19] The NWU students were assigned into groups at the beginning of the second semester and kept the same groups for the entire semester.