



## Students' Expectations about an Innovative Introductory Physics Course

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### ABSTRACT

Beginning the Fall Semester of 2001, the Physics Department at Purdue University started to teach a calculus-based introductory physics course by using a modeling-based interactive engagement method. In brief, modeling in physics is defined as “making a simplified, idealized physics model of a messy real-world situation by means of approximations”. This study explores physics majors' expectations, attitudes, and beliefs about a university physics course based on modeling instruction and interactive engagement. Also, this study investigates how those expectations, attitudes, and beliefs compare to that of students for other physics courses and change as a result of physics instruction. The Maryland Physics Expectation (MPEX) survey is used. It is a 34-item Likert-scale survey that investigates students' attitudes, beliefs, and expectations about physics. It was administered as a pre-and post-test. The results lead to the conclusion that the instruction based on modeling and interactive engagement produces an average deterioration in student expectations, attitudes, and beliefs. In spite of this fact, it should not be disregarded that students at Purdue University have closer views with most scientists (more favorable views) at the beginning of the course and the end of the course than students at other universities have. That suggests that students' expectations, attitudes, and beliefs about a physics course based on modeling and interactive engagement are more sophisticated and professional than that of students for other physics courses when compared to that of students in other physics courses at other universities.

**Keywords:** Attitudes; Beliefs; Expectations; MPEX; Physics

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### INTRODUCTION

Most professors in an introductory physics course even in reform curricula-based courses expect students do and think “like a physicist” (Redish, 1997) without considering what students expect. What does mean “thinking and doing like a physicist”? It means not just memorizing some facts, equations, and some processes. It involves some processes such as understanding of the nature of science; making connections between science and the real world; and understanding of process of physical phenomena. Therefore, it can be true to say that there is a large gap between students' expectations and professors'

expectations. In the Maryland Physics Expectations (MPEX) project, the Physics Education Research Group at the University of Maryland investigated the distribution of student expectations at the beginning of the course, the effect of their expectations on their behavior during the course, and the effect of the course on changing their expectations (Redish, 2002). Likewise, the results of their study indicate that there is a significant gap between expert responses to this survey and that of novice students.

The meaning of "student expectations" is "what students expect will happen in the class, what they expect to do, and what they believe is the nature of science and scientific learning". In other words, these expectations are related to context expectations not content expectations. Redish et al., (1998) determines expectations as follows:

...we use the phrase expectations to cover rich set of understandings. We focus on what we might call students' "*cognitive expectations*-expectations about their understanding of the process of learning physics and the structure of physics knowledge rather than about the content of physics itself (p.213).

Building upon the line of inquiry by Redish et al. (1998), we wanted to probe students' expectations, attitudes, and beliefs about a university physics course based on modeling instruction and interactive engagement. Also, how their expectations, attitudes, and beliefs compare to that of students for other physics courses, and whether their expectations change after the new physics instruction. Students' expectations in a calculus-based introductory physics course play an important role for students to react to their course. Their expectations affect their learning and understanding. Redish et al. (1998) explain how important students' expectations are and how their expectations affect their learning and understanding;

What students expect will happen in their introductory calculus-based (university) physics course plays a critical role in how they respond to the course. It affects what they listen to and what they ignore in the firehose of information provided during a typical course by professor, teaching assistant, laboratory, and text. It affects which activities students select in constructing their own knowledge base and in building their own understanding of the course material. The impact could be particularly strong when there is a large gap between what the students expect to do and what the instructor expects them to do (p.212).

Students also bring their experiences into the physics class other than physics knowledge. Each student has different experiences so there will be variety of expectations, attitudes, and beliefs concerning what kind of things students will learn (Im & Pak, 2004). Moreover, their preconceptions affect their understating about what they hear from their instructor. Redish et al. (1998) explains students' expectations and effects:

It is not only physics concepts that a student brings into the physics classroom. Every student, based on his or her own experience, brings to the physics class a set of expectations -- attitudes, beliefs, and assumptions -- about what sort of thing they will learn, what skills will be required, and what they will be expected to do. In addition, many of them will have a view as to the nature of scientific information that affects how they interpret what they hear. In this paper, we use the phrase student expectations to cover this rich set of understandings (p.212).

In this paper, it was intended to show how instructional practices and curricular elements explicitly promote students' expectations, attitudes, and beliefs (Elby, 2001). As a result, this development in their expectations, attitudes, and beliefs can lead to

significant improvement in students' views about knowledge and learning. Due to some constrictions, I found out there is deterioration in students' expectations, attitudes, and beliefs. Explanations about that can be found in the last part.

## **TEACHING METHOD**

### **a) Modeling-Based Interactive Engagement**

Beginning the Fall Semester of 2001, the Physics Department at Purdue University started to teach a calculus-based introductory physics course by using a modeling-based interactive engagement method. To be precise, "modeling" as used here has a different meaning from "modeling" used in the notation of science education. In brief, modeling in physics is defined as "making a simplified, idealized physics model of a messy real-world situation by means of approximations" (Chabay & Sherwood, 1999). It is also called "physics modeling" in the physics education community. In this course, physics modeling and computer simulations are used to promote conceptual understanding along with interactive engagement method. Hake (1998) defines "Interactive Engagement (IE) methods as those designed at least in part to promote conceptual understanding through engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors..." (p.65) In other words, it is a method that improves students' conceptual understanding by their interactions with each other using their thoughts and some hands-on activities. Then, they can have immediate feedback from their discussions with their peers, their teaching assistants, or their instructors. Modeling-based interactive engagement instruction involves some features focusing on the development of conceptual understanding:

### **b) Physics Modeling**

A physics model in the physics-education community is considered as a simplified and idealized physical system, phenomenon, or idealization. According to Greca & Moreira (2001), the physics models determine, for instance, the simplifications, the connections, and the necessary constraints. As an example one can think of a point particle model of a system in classical mechanics. A simple pendulum is another example of a physics model because it is idealized and consists of a mass particle on a massless string of invariant length moving in the homogenous gravitational field of the Earth in the absence of drag due to air (Czudkova & Musilova, 2000).

In Purdue's calculus-based introductory physics course, students do not use models which are already created in this course. They apply the fundamental principles and create their own models. Modeling involves making a simplified, idealized physics model of a messy real-world situation by means of approximations. Then, the results or predictions of the model are compared with the actual system. The final stage is to refine the model to obtain better agreement, if needed. Sometimes it may not be needed to modify the model to get more exact agreement with the real-world phenomena. Even though the agreement may be excellent, it will never be exact since there are always some influences in the environment that we cannot consider while we are building the models. For instance, while a rock is falling, the gravitational pull of the earth and air resistance are the main influences. However, there are also other effects such as humidity, wind and weather, Earth's rotation, even other planets (Chabay & Sherwood, 1999).

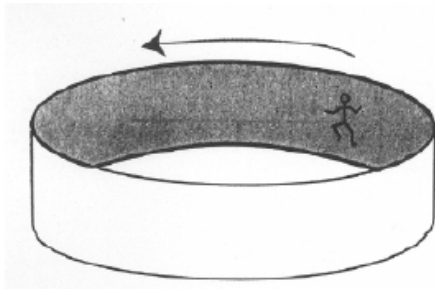
In physics modeling (Chabay and Sherwood, 1999), the following process is followed: Start from fundamental principles which are the linear momentum principle, the energy principle, and the angular momentum principle; Estimate quantities; Make

assumptions and approximations; Decide how to model the system; Explain / predict a real physical phenomenon in the system; and Evaluate the explanation or prediction.

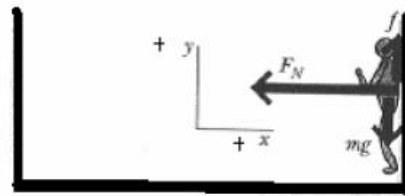
In summary, physics modeling is analysis of complex physical systems by means of making conscious approximations, simplifications, and idealizations. When students make approximations or simplifications, they should be able to explain why they make them. For instance, in modeling a falling ball, in general, air resistance is neglected. So, there is no force contribution from air resistance. While students do neglect it, they should be able to have reasons for this.

The following example shows how to make use of physics modeling to explain a real-world phenomenon, which can also be considered as a physics problem.

An amusement park ride (Chabay & Sherwood, 2002, p106): There is an amusement park ride that some people love and others hate in which a group of people stand against the wall of a cylindrical room of radius R, as the room starts to rotate at higher and higher angular speed  $\omega$  (Figure 1). When a certain critical angular speed is reached, the floor drops away, leaving the people stuck against the whirling wall. Explain why the people stick to the wall without falling down. Include a carefully labeled force diagram of a person, and discuss how the person's momentum changes, and why.



**Figure 1.** An Amusement Park Ride (Chabay & Sherwood, 2002, p106)



**Figure 2.** Physics Diagram of the Person. At this Instant the Person is Moving in the  $-z$  Direction

Starting from a fundamental physics principle which is the momentum principle in this situation, we can determine the known forces and draw the force diagram (Figure 2). In Figure 2, the person shown has a mass  $m$  and moving in the  $-z$  direction. Because of its gravity, the earth exerts a force  $mg$  which is downward ( $-y$ ). The wall exerts a friction force which has a  $y$  component  $+f$  because the person is not falling, and  $x$  component  $-F_N$  normal to the wall because the person's momentum is changing direction. The vertical component  $f$  of wall force is a frictional force. If the wall has friction which is too low, the person will not stick to the wall. So,  $f \leq \mu F_N$  ( $\mu$  is the coefficient of friction).  $\mu$  has a value which ranges between 0.1 to 1.0. The angular speed should be enough large.

There is momentum change inward; if the net force were zero, the person would move in a straight line. From circular motion (no change in  $y$  direction), and the momentum principle, we can find  $F_N$  to show why the people stick to the wall without falling down.

$$\frac{d\vec{p}}{dt} = \langle -F_N, (f - mg), 0 \rangle \quad p_y = 0, \text{ so } \frac{dp_y}{dt} = 0$$

$$\left| \frac{d\vec{p}}{dt} \right| = \omega p, \quad p = \left| \vec{p} \right|$$

Circular motion with constant  $p = \left| \vec{p} \right|$

$$F_N = \omega p \text{ and } f = mg$$

Combining the above two equations,

$$p = mv = m \frac{d\vec{R}}{dt} = m\omega R, F_N = \omega p = m\omega^2 R$$

Thus, using  $f \leq \mu F_N$ , we can find  $mg \leq \mu(m\omega^2 R), \omega^2 \geq \frac{g}{\mu R}$ . The smaller the friction,

the higher the angular speed needed. When the frictional force is smaller than the gravitational force, people cannot stick to the wall and slide down. For this reason, the angular speed has to be large enough to make the frictional force greater than the gravitational force.

### c) Computer Simulations

In this course, students write programs to simulate physical systems using VPython (Scherer et al., 2000). VPython makes students focus on the physics computations to obtain 3-D visualizations. Students can do true vector computations, which improves their understanding of the utility of vectors and vector notation. For example, students can study the motion of the earth in orbit around the sun by means of writing a program.

Creating simulations by writing computer program using VPython helps students understand physics because they can see how physics principles work.

The modeling-based interactive engagement method defined by Chabay & Sherwood (2002) can offer the potential to promote enhanced learning in conceptual understanding of physics (Örnek, 2007).

## METHODOLOGY

### a) Subjects and Settings

This study took place in the Physics Department at Purdue University throughout the Fall, 2004 semester. For this study, I focused on a calculus-based introductory-level physics course which includes lecture, small-group work, which is called “recitation” in a traditional physics course, and computer modeling. During the small-group work and computer modeling, not only teaching assistants but also the instructor was involved. There were, in general, eight small groups of three or four students in each of three sections. Each small group had a small white board in which to solve physics problems.

In the class, students were mostly physics majors. Also, more than half of the class had math and physics background.

### b) Data Collection

The Maryland Physics Expectation (MPEX) survey (Redish et al., 1998) was used. The survey is well-known and widely used in the universities of the US and other countries. It is a 34-item Likert-scale (agree-disagree) survey that investigates students’ attitudes, beliefs, and expectations about physics. The items in the survey were rated on a five point Likert-scale from strongly disagree (1) to strongly agree (5). The instructor administered it at the beginning of the Fall, 2004, and the end of the Fall, 2004, semester as a pre-test and a post-test in PHYS 162, which treats Particles, Kinematics, and

Conservation Laws. Due to only using a matched-pair samples, N=38 students completed pre-and post test.

### c) Data Analysis

The Maryland Physics Expectation Survey (MPEX) (Redish et al., 1998) probes students' expectations, attitudes, beliefs, and assumptions about an introductory physics course using a Likert-scale. The MPEX survey was tested for both reliability and validity. The overall survey has a Cronbach's alpha coefficient of 0.81. This number indicates that the overall survey score is reliable because its Cronbach's alpha coefficient is greater than 0.70 (George & Mallery, 2003). Validity was demonstrated by studying the results of chosen groups and more than 120 hours of student interviews by the Maryland Physics Education Research group. The results of two methods indicated that both faculty and students agreed with interpretation of the Maryland Physics Education Research group of the MPEX survey items and what they consider to be an expert response (Saul, 1998).

I used it to find students' expectations, beliefs, and attitudes about an introductory physics course and whether their expectations, beliefs, and attitudes changed as the course proceeded. Also, I wanted to compare students' expectations, beliefs, and attitudes in Phys 162 to students in other universities.

The survey addresses six different categories: Independence, Coherence, Concepts, Reality Link, Math Link, and Effort. Students' views in each area are categorized in two different ways. If the view agrees with the views of most scientists, then it is called an *expert* or *favorable* view by the Maryland group. If the view agrees with the views of most beginning students, then it is called a *novice* or *unfavorable* view. Using the SPSS statistics program and choosing descriptive statistics, I calculated the percentage of students giving favorable (expert)/unfavorable (novice) responses over all the categories and for the six different categories of the MPEX survey for both pre-and post tests.

The inventory classifies students as tending toward expert or novice in six different areas.

1. Independence - beliefs about learning physics-receiving information (novice) or using an active process of reconstructing one's own understanding (expert);
2. Coherence - beliefs about the structure of physics knowledge - a collection of isolated pieces (novice) or a single coherent system (expert);
3. Concepts - beliefs about the content of physics knowledge-formulas (novice) or concepts that underlie the formulas (expert);
4. Reality Link - beliefs about the connection between physics and reality-whether physics is unrelated to experiences outside the classroom (novice) or whether it is useful to think about them together (expert);
5. Math Link - beliefs about the role of mathematics in learning physics-whether the mathematical formalism is just used to calculate numbers (novice) or is used as a way of representing information about physical phenomena (expert);
6. Effort - beliefs about the kind of activities and work necessary to make sense out of physics-whether they expect to think carefully and evaluate what they are doing based on available materials and feedback (expert) or not (novice).

If a student's view agrees with the views of most scientists, then the student has an expert or favorable view. If the student's view agrees with the views of most beginning students, then the student has a novice or unfavorable view. Table 1 shows categories and questions on the MPEX.

**Table 1.** Categories and Questions on the MPEX (Redish, et al. 1998)

Categories	Favorable (Expert) and Unfavorable (Novice) on MPEX
Independence	1, 8, 13, 14, 17, 27
Coherence	12, 15, 16, 21, 29
Concepts	4, 19, 26, 27, 32
Reality links	10, 18, 22, 25
Math links	2, 6, 8, 16, 20
Effort	3, 6, 7, 24, 31

MPEX results at other universities in Table 2 were obtained from Redish’s study (1998) in order to compare students’ expectations at Purdue University to other universities. Also, it was shown the instructional characteristics of each university including Purdue University.

**Table 2.** Characteristics of Physics Courses of Different Universities (Redish et al., 1998) Including Purdue University.

Institution	Instructional Characteristics	N
University of Maryland College Park (UMCP)	Traditional lectures, some classes with group-learning tutorial instead of recitation, no lab	445
University of Minnesota Minneapolis (UMN)	Traditional lectures, with group-learning research designed problem-solving and labs	467
Ohio State University Columbus (OSU)	Traditional lectures, group-learning research designed problem-solving and labs	445
Dickinson College (DC)	Workshop Physics Laws (1991), no formal lectures. Instead, activities and observations. Observations are enhanced with computer tools for the collection graphical display, analysis and modeling of real data	115
A small public liberal arts university (LA)	Workshop Physics	12
Purdue University	Modeling-based interactive teaching consists of three parts, interactive lectures, small group work, computer labs, and no regular labs	38

**Table 3.** MPEX Results (% Favorable/% Unfavorable) from Different Universities (Redish et al., 1998) including Purdue University.

	Overall	Independence	Coherent Link	Concept Link	Reality	Math	Effort	N
Purdue University								
Pre	72/18	57/22	60/21	65/16	68/14	63/16	54/20	38
Post	59/17	54/18	58/21	67/13	67/09	56/17	49/26	38
UMCP								
Pre	54/23	54/25	53/24	42/35	61/14	67/17	67/13	445
Post	49/25	48/27	49/27	44/32	58/18	59/20	48/27	445
UMN								
Pre	59/18	59/19	57/20	45/27	72/9	72/11	72/11	467
Post	57/20	58/20	61/17	46/28	69/10	72/12	63/16	467
OSU								
Pre	53/23	51/24	52/21	37/36	65/10	65/13	66/19	445
Post	45/28	46/28	46/26	35/35	54/17	55/20	44/30	445
DC								
Pre	61/15	62/14	58/17	47/23	76/4	70/10	75/7	115
Post	60/19	67/14	66/18	58/23	72/9	71/12	57/26	115
PLA								
Pre	57/23	57/27	57/26	38/46	71/13	74/11	72/8	12
Post	49/31	52/22	47/33	45/34	52/25	54/19	48/30	12

According to Table 3, the attitudes and expectations of beginning students at Purdue University are more favorable than that of students at other universities; also the attitudes and expectations of exiting students at Purdue University are more favorable than that of students at other universities except DC.

On the independence category, students' initial views are more favorable than unfavorable in a range from 54% (UMCP) to 62% (DC). Students' initial views at Purdue University are slightly higher than UMCP, OSU, slightly lower than DC, UMN, or the same with other universities, PLA. Most universities, including Purdue University, showed a small deterioration on this category, except for DC (slight improvement from 62% to 67% favorable responses).

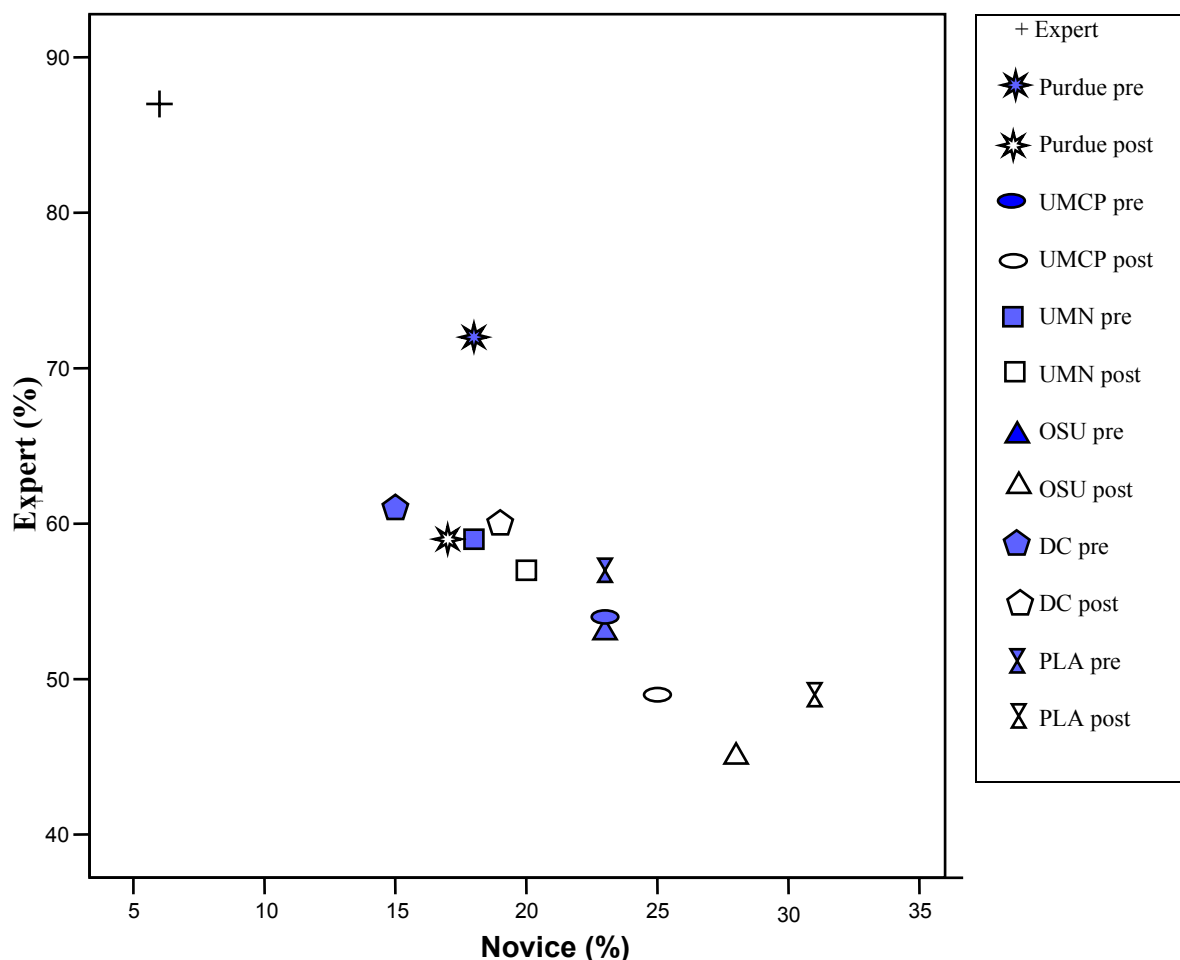
On the coherence category, the initial views of students are more favorable than unfavorable responses in a range from 60% (Purdue) to 52% (OSU). Students' initial views at Purdue University are slightly higher than other universities. Most universities including Purdue University showed a deterioration on this category except for UMN (slightly improvement from 57% to 61% on favorable responses), DC (improvement from 58% to 66%).

On the concepts category, the initial views of the students of this category are favorable between 37% (OSU) to 65% (Purdue). Students' initial views and final views at Purdue University are much higher than other universities. All universities showed some improvement on this category except OSU, which showed a small deterioration on favorable responses.

On the reality link category, the students at all universities started with quite strong favorable responses, ranging from 61% (UMCP) to 76% (DC). Unfortunately, each university showed deterioration on this category. Some of the decreases are substantial such as PLA—from 71% to 52%. The shift at Purdue University is very small from 68% to 67% favorable responses.

On the math link category, although the students at all universities started with fairly strong favorable responses, ranging from 65% (OSU) to 74% (PLA), some of the universities do not show improvement in the favorable ratio except DC. Purdue University shows deterioration from 63% to 56% on favorable responses.

On the effort category, the initial views of the students at all universities begins quite high, ranging from 54% favorable (Purdue) to 75% favorable (DC). By the end of semester, the decrease happened drastically, with three universities dropping in the favorable percentages by about 20% (UMCP, OSU, and PLA), and two dropping by 10% and 15% (UMN, DC). The decrease is the smallest at Purdue University even though students started out with less favorable percentages when we compare it to other universities.



**Figure 3.** Overall Percentages of Different Universities (Redish et al.,1998) and Purdue University Added.

The overall survey results for the different universities are presented in Figure 3. The results of the expert group are shown by +. The initial test results of the students at all universities differ from the expert results. Beginning students at Purdue University agreed with the expert responses 72% of the time which is more than the students' initial tests in other universities. Interestingly, the percentage of Purdue students, 72%, is close to that of experts, 87%. However, the percentage of the post-test is a decrease in expert responses from 72% to 59% overall and falls right in line with other universities. Even though the percentage of Purdue students is less than that of experts, it is higher than all other universities except Dickinson College (DC). Thus it appears that the instruction produces an average deterioration rather than an improvement of student expectations. Possible reasons for this decrease are discussed in conclusion.

## RESULTS

I wanted to answer the following questions: "How do students' expectations, attitudes, and beliefs about a physics course based on modeling instruction and interactive engagement compare to that of students for other physics courses? Do the expectations, attitudes, and beliefs of students in the modeling-based instruction and interactive engagement course change as the course proceeds?"

According to the results of this study, the answers of the questions are:

Most students enter their science courses having some expectations, attitudes, and beliefs about the nature of a physics course. Students' expectations, attitudes, and beliefs towards the physics course overall were examined to determine if modeling-based and interactive engagement affected how students felt about the course throughout the course.

The expectations, attitudes, and beliefs of beginning students are more favorable than that of students at other universities. Moreover, the expectations, attitudes, and beliefs of students completing the course at Purdue University are more favorable than that of students at other universities.

The overall initial expectations, attitudes, and beliefs of the students at all universities differ from faculty's expectations, attitudes, and beliefs (EABs). Beginning students at Purdue University agreed with the faculty's EABs 72% of the time which is more than the initial EABs of students of other universities. It is interesting that the percentage of Purdue students, 72% is close to that of faculty, 87%. On the other hand, the percentage of post-test EABs for Purdue students decreased 72% to 59%. Although the percentage of Purdue students is less than the percentage of experts, it is higher than all other universities except Dickinson College (DC).

## CONCLUSION AND DISCUSSIONS

The results lead to the conclusion that the instruction based on modeling and interactive engagement produces an average deterioration in student expectations, attitudes, and beliefs. In spite of this fact, it should not be disregarded that students at Purdue University have closer views with most scientists (more favorable views) at the beginning of the course and the end of the course than students at other universities have. That suggests that students' expectations, attitudes, and beliefs about a physics course based on modeling and interactive engagement are more sophisticated and professional than that of students for other physics courses when compared to that of students in other physics courses at other universities

In addition to the possibility that students may think that their expectations were not fulfilled in this course, there is another possible reason for the students showing a decrease in their expectations, attitudes, and beliefs about physics: The post-test was at the week before the final exam. Therefore, students were so busy that they did not want to spend their time for this survey and did not pay attention as much as they did in the pre-test. I saw them fill in the choices without even reading. They were randomly making the choices. On the other hand, other universities show a decrease in their expectations, attitudes, and beliefs about physics at the end of the course as well.

These results deduce that instructors need to know that students' expectations, attitudes, and beliefs about a physics course are considerably different from experts' expectations, attitudes, and beliefs about a physics course. This reality causes instructors to reflect on teaching methods of physics. Marshal & Linder (2005) state that knowing students expectations, attitudes, and beliefs, about a physics course may contribute education teacher development.

Our characterization of students' expectations of teaching may also have the potential to contribute to higher education teacher development initiatives. It provides a framework for thinking about range of possible aims or intentions for undergraduate physics teaching, as well as the associated teaching practices that students experience as effective in meeting their teaching expectations.

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