STATEMENT OF CURRENT RESEARCH ACTIVITIES: 2001

My research since July 2001 has been associated with an ongoing NSF's Research on Learning and Education (ROLE) grant titled "Technology & Model-Based Conceptual Assessment: Research in Students' Applications of Models in Physics & Mathematics" (P.I. Dean Zollman). The proposal for the ROLE grant states that goals of this project are to:

1. "measure and trace students' states of understanding and changes in those states during instruction for time periods ranging from a single class session to several weeks of instruction.
2. provide real-time feedback on the state of student conceptual understanding during an individual class period and/or between two consecutive class sessions,
3. develop tools which will promote research in ongoing classes (sometimes called action research) among instructors with interests in learning more about their students' states of understanding and in using that knowledge to improve their teaching,
4. create these tools so that they can be used effectively in classes ranging from small seminars to large lectures,
5. provide researchers and teachers with information about the transfer of knowledge between physics and mathematics,
6. provide an opportunity to study how students and instructors interact with a new teaching environment which enables rapid feedback on the level of student understanding and transfer."

At this stage of the project, we are focusing primarily on the first and by far the most important of the goals above. I was involved in efforts toward this goal:

Students Mental Models and their Applications in Newton's II Law

Most previous research has focused on whether students solve a given problem correctly or incorrectly, and their main misconceptions. Relatively less research has been done on how students apply their mental models in different contexts and how these models change with instruction. We decided to investigate the mental models that students in a calculus-based introductory physics class (E.P.-II) use to analyze Newton's II Law problems. Our research methodology incorporated the following:

- Case study interview of a group of students three times during the semester.
- Short multiple-choice survey questions to be give to the students a three times during the semester. The questions were created based on the responses in the interviews.

Students were interviewed and surveyed three times. The first time was before they covered Newton's Laws in class. The second time was just after they had covered this material in class and eventually several weeks after they had covered the material.

Our interview and survey results showed that most students prior to covering the material in class had applied an Aristotelian model to the Newton's II Law questions. Most of these students changed to the Newtonian model after instruction. However, a few weeks after they had had instruction in other topics, some of these students reverted back to the Aristotelian framework when in the context of different physical situations. Even in a single context some students are in a mixed mental models state i.e. they apply a different model depending upon the physical parameter of the context that is being varied. For instance, if students are asked how the motion of a box would change if the constant force that was initially applied to move it at a constant speed were eliminated, students would correctly apply the Newtonian model and state that the box would slow down to a stop. However, in the same context of a box, if students were asked what force would be needed to move the box at twice the speed as before, some may apply the Aristotelian model. These results indicate that students' mental models in Newton's II Law situations change with the context. Moreover, while students mental models may change with instruction, sometimes these mental models revert back to previously held models several weeks after instruction, or when applied in different contexts.

We will continue work on this investigation in Spring 2000 with E. P. – II students. Salomon Itza-Ortiz (postdoc) collaborated with me on this project.

The Effect of Order on Student Performance on Surveys

In our research on student mental models in various contexts we encountered a previously reported, but not widely studied phenomenon: Students performed differently when the order in which the context was presented to was reversed. In the two contexts that we presented to students in our surveys, we found that students who were asked to answer the survey where the context that was less real world like was presented first, performed better in both contexts.

We speculate the following reason for this phenomenon: When students are first presented with a context that is real world like, they are more likely to use their naïve real-world mental models e.g. the Aristotelian model, that are often incorrect. When they are later presented with a context that is less familiar, they continue to apply this model, because these models are often very deeply rooted in their understanding of the world around them. However, when students are presented with the unfamiliar context first, they are less likely to rely on their naïve understanding and are more likely to use what they have learned in a physics class e.g. the Newtonian model. Later when these students are presented with the real-world context they may not revert back to the naïve Aristotelian model, but rather continue to use the Newtonian model that they used in the first context, thereby causing an increase in the overall performance in both the familiar as well as the unfamiliar context.

When the same questions were presented to the students after they have covered the material in class, the "order effect" described above was virtually non-existent. This is consistent with the above explanation because after students had studied the material, the new 'Newtonian' model would have replaced the 'Aristotelian' one in the minds of most students. Also, after having been presented with both contexts in the physics class, neither of the contexts may have appeared to be more 'real-world' than the other i.e. they were both perceived as physics problems and invoked ideas studied in the physics class. Therefore neither of the two contexts was more or less likely to trigger the naïve Aristotelian model than the other one.

We are continuing our work on this investigation in Spring 2000 with General Physics-I students. Kara Gray (Undergraduate Physics major) will be working with me on this project.

Thanks are due to *Amit Chakrabarti,* faculty member teaching the E.P.-I class for consultations and for access to his students during lecture and afterwards.

The Use of Physics Terms in Everyday Language and Their Impact of Student Learning

Several words (e.g. Force, Momentum, Impulse, Work, Energy & Power) are used in everyday language. These words are also used in physics. The meanings of these words in everyday language may be quite different from its specific meaning in physics. We believe that this discrepancy in meanings may pose a barrier to understanding the physics concept that they represent. To test this hypothesis we surveyed students in a Physical World class several times during the semester both before and after each of these terms had been introduced.

In surveys before the term was introduced, students were asked to create three sentences that used the word (e.g. 'force') or a form of it (e.g. 'forcing', 'forced' etc.). We analyzed the surveys to categorize the ways in which the word was used (i.e. noun, verb, etc). We noticed differences between students who had taken physics in high school and those that had not. After the term was introduced in class, the students were surveyed again. This time they were presented with three sentences that were representative of the sentences that students had created in the previous survey. For each sentence, students were asked to explain how the way in which each word was used in the sentence was both similar and dissimilar to the way in which the word was used in a physics class. Results indicated that those students who were able to clearly explain the similarities and dissimilarities between the usages of the word in the sentence provided and the physics usage scored higher in exam questions that required the use of the word. Similar results were obtained with the use of the words 'Momentum' and 'Impulse'.

These results indicate that there is a correlation between the conceptual understanding of the physics concept and an ability to discern both the similarities and the dissimilarities between the physics meaning of a word and its everyday usage. Students who were able to describe the similarities and dissimilarities between the physics and everyday meanings of the word, scored higher on exam questions where these words were used.