

The Effect of Initial Conditions and Discussion on Students' Predictions for Interactive Lecture Demonstrations

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Abstract. Over the past eight years at McDaniel College, students' Predictions for various Interactive Lecture Demonstrations (ILDs) have improved markedly. One explanation is that students have become increasingly sophisticated in their understanding of kinematics and dynamics. Another possible explanation is that the class as a whole is only slightly more sophisticated, and during the Discussion Phase of the ILD the correct Predication is very successfully transmitted within groups *and* between groups. The purpose of this paper is to support the proposition of this possible explanation. To begin to address this idea, I present an overview of and results from a preliminary, computer-based simulation of classroom discussion.

Keywords: physics instruction, undergraduate, computer simulation, interactive lecture demonstrations

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INTRODUCTION

Since 2000, I have been teaching one section of *General Physics I* each Fall at McDaniel College.[1] This course is part of a calculus-based sequence and the only introductory physics course offered at McDaniel. As part of my instruction, I have included Interactive Lecture Demonstrations (ILDs), which are materials designed to improve understanding of physics through cycles of prediction-observation-resolution.[2] I will not describe the full implementation of ILDs, but a presentation of some background is necessary to put this paper in context.

A Demonstration begins with the instructor performing a simple experiment, such as rolling a cart along a track. After witnessing a Demonstration, students make specific Predictions on their *Prediction Sheets*. For the aforementioned experiment, students would be directed to graph the position and velocity of the cart as functions of time. Once students have made their Predictions, they discuss them with their classmates sitting nearby. (Since 2000, the structure and character of this discussion has gone unchanged in my class.) After this Discussion Phase, the instructor elicits Predictions from a few students, which are drawn on the board by the instructor. The Demonstration ends with the instructor repeating the experiment, but at this point the data relevant to the Predictions are collected in real-time by a computer and projected for the students to see. Students copy the results on their *Results Sheets*. The signed *Prediction Sheets* are

collected at the end of class or, if part of a booklet, at the end of the term.

Since there will be a need to distinguish between the number or percentage of correct Predictions before and after the Discussion Phase, I will use the following notation: $P_c(t)$ refers to Predictions made prior to Discussion, while $P_c(f)$ refers to Predictions made after Discussion

For the first few years students' Predictions for the various Demonstrations were expectedly varied; $P_c(f)$ was relatively low. As years passed, the number of incorrect Predictions offered at the end of the Discussion Phase decreased (which means $P_c(f)$ increased), and in some cases, incorrect Predictions were entirely absent. To confirm these trends, I analyzed students' *Prediction Sheets* for three ILDs.

ILD DATA AND ANALYSIS

I analyzed students' *Prediction Sheets* for the first three ILDs of the term: one-dimensional kinematics and dynamics and Newton's Third Law. I limited my analysis to Predictions with easily categorized responses (correct or incorrect). Graphical and "Yes-No" responses fit well into this group, and these types of responses constituted the vast majority on these ILDs. First, I grouped all these Predictions together ("Overall"). Later, I labeled as "Difficult" Predictions which, in 2000, fewer than 50% of the students answered correctly. There were roughly seventeen Predictions Overall and roughly seven Difficult ones. ("Roughly" because in some years

time constraints prevented completion of the entire ILD.) Results are in Table 1. There is a clear and markedly upward trend in $P_c(f)$ in both cases.

Table 1. Percentages of correct ILD Predictions—Overall and Difficult items—and statistics for the best-fit line to the data

Year	Overall: $P_c(f)$ %	Difficult: $P_c(f)$ %
2000	56.5	39.6
2001	66.7	45.9
2002	72.8	63.3
2003	72.1	58.5
2004	76.0	60.0
2005	83.1	73.1
2007	81.3	74.6
Best-fit line		
<i>Slope</i>	3.4 ± 0.7 %/year	4.9 ± 1.0 %/year
R^2	0.83	0.84

THE QUESTION

Given the observed trend in $P_c(f)$, one may postulate several mechanisms accounting for all or part of this phenomenon. A simple explanation is that students' level of understanding became increasingly sophisticated. Regrettably, I have no relevant diagnostic test results to analyze. Apart from this reasonable explanation, there is another, more subtle, possibility. Students finalize their Predictions only after they have discussed them with their peers. It is conceivable that $P_c(f)$ depends, perhaps quite strongly, on $P_c(0)$ as well as on the character of the discussion. So the question becomes: To what extent is $P_c(f)$ influenced by $P_c(0)$ and by the nature of the interactions during the Discussion Phase?

MODEL OVERVIEW

To investigate this question, I endeavored to roughly simulate the influence of $P_c(0)$ on $P_c(f)$, as well as the effects of intra-group and inter-group discussion. To do so, I developed a computer model using Stella®.[3] This program is marketed primarily for researchers modeling biological systems; however, it holds no intrinsic assumptions preventing application to sociological systems.

This preliminary article covers only a broad overview of the model. I start with an introduction to terminology. In the context of the model, the word "idea" represents $P_x(t)$. Ideas are either I or $-I$, correct or incorrect. Some may find this reductionist approach sophomoric. However, remember, this simulation models what students write on their *Prediction Sheets*, which is considerably less amorphous than thoughts. Next, "communication" models real-world communication occurring during

the Discussion Phase, including talking, gesturing, and illustrating. Finally, when communications fail to change the ideas of the members of a group, that group is "content," and further communication is deemed unwarranted.

There are three layers to this model. First, the student; then the group, composed of three students; and at the top, eight groups constitute the class. The simulation begins by assigning each student an idea. Students then communicate ideas to group members. These communications occur one at a time (although interruptions occur) for varying lengths of time and intervals. By receiving ideas, students may change their ideas. Additionally, simply communicating may shift the communicator's idea. After some discussion, students within a group settle on their ideas, and the group becomes content. At this point, they eavesdrop on communications among students in the two neighboring groups. When a student overhears an idea from another group that shifts that student's idea, that new idea is communicated to the group. This begins a new round of intra-group communication; however, communications will generally be fewer because the threshold for "contentness" will be lower. Additionally, while a group is content, or not, an individual's idea may spontaneously shift so that the student will want to communicate it to the group. If this happens when the group is content, it shakes them out of their state, and communication renews. Like before, the contentness threshold is lowered.

How are all these interactions mediated? As the simulation commences, the program randomly assigns each student an idea state: I or $-I$. I have assigned certain probabilities to all interactions. For example, if a student with an incorrect idea is communicated a correct idea, there is a modestly high probability the receiving student will change idea states. Conversely, a student with an incorrect idea who is communicated another incorrect idea is unlikely to change to a correct idea. Inter-group communication impacts students' ideas as intra-group communication, although the probabilities of conversion are lower. And the model incorporates internal mechanisms for individual state shifts, which are also dictated by probabilities.

Activities of students interacting with other members of their group is controlled at the group level of the model. Such activities include determining who speaks, when, and for what time interval, and how long it takes a group to become content. Again, at every instance in the simulation all of these are determined probabilistically.

To give the reader a sense of the structure of the model, Figure 1 holds a screen capture of one group of students in the Stella modeling environment.

MODEL ANALYSIS AND LOOKING FOWARD

In the model, discussion generally had a positive influence on $P_c(f)$. Additionally, permitting students to interact with other groups sharply increased $P_c(f)$. Finally, when $P_c(0)$ is low, the effects of discussion are greatest.

Working backwards with some information in Table 1 is quite illuminating. Focusing on results for “Difficult” items, $P_c(f)$ lies somewhere between nine and ten students (out of twenty-four) in 2000. The average values from both simulations imply that only about three people may have initially conceived the correct Prediction before the Discussion Phase. In 2007, $P_c(f)$ hovered around twenty students. Again working backward, the model with no inter-group discussion suggests that only about fourteen people came up with the correct Prediction on their own. The model with inter-group discussion (which is more like the environment my students experienced throughout all the ILDs over the years), suggests that $P_c(0)$ may be fewer than seven people. The change in $P_c(f)$ from 2000 to 2007 was ten or eleven, but the change in $P_c(0)$ may have been fewer than four!

Again, I do not want to seem willing to place undeserved emphasis on the numerical results from these simulations. The above examples are intended only to help the reader understand what the model, at this stage, predicts. Nevertheless, there is a lesson here: small shifts in a class’s initial knowledge state could be greatly amplified by discussion. Instructors should avoid rushing to modify pedagogy based on the number of correct responses held by students

after discussion. Widespread agreement may be the result of such discussion, so jettisoning that discussion could be detrimental. Additionally, apparent consensus on any attractive idea (correct or otherwise) may not truly reflect a wider range of beliefs held by individual students.

Looking ahead, I recognize the necessity for tying this work to the larger body of literature, as other investigators surely have insights into modeling complex interactions. Also there is room for field research. Specifically, I could more closely monitor student interactions in class, which would help me design a richer model and focus on more appropriate values for parameters already in the model.

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NOTES AND REFERENCES

- a. Contact information: jmarx@mcdaniel.edu
 1. Except for a sabbatical leave in 2006.
 2. D. Sokoloff and R. Thornton, “Interactive Lecture Demonstrations,” Wiley, 2001.
 3. B. Hannon and R. Matthias, “Dynamic Modeling: 2nd Edition,” Springer, 2001.

APPENDIX

Table 2. This table lists model parameters, their descriptions, and values for the simulation results shown above.

<i>Parameter name</i>	<i>Value</i>	<i>Description</i>
<i>LAYER 1: STUDENT</i>		
C turns I to C	0.5	The probability of a state change when a student... with an incorrect idea is communicated a correct idea
C turns C to I	0.005	with a correct idea is communicated a correct idea
I turns C to I	0.02	with a correct idea is communicated an incorrect idea
I turns I to C	0.005	with an incorrect idea is communicated an incorrect idea
C to I self	0.01	communicates a correct idea
I to C self	0.025	communicates an incorrect idea
C spy turns I to C	0.2	with an incorrect idea is communicated a correct idea by a student outside the group
I spy turns C to I	0.008	with a correct idea is communicated an incorrect idea by a student outside the group
random change from I to I	0.005	spontaneously shifts from one incorrect idea to another incorrect idea
<i>LAYER 2: GROUP</i>		
contentedness kernel	8	Establishes the... threshold for when groups initially become content
windedness kernel	5	average time interval for each communication
inactivity	4	average time interval between communications
<i>LAYER 3: CLASS</i>		
ratio init correct	variable	The probability that any student will have an initially correct idea
spy toggle	1 or 0	Activates or deactivates communication between groups