# Research-Based Perspectives on Science and Mathematics Education

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# Outline

1. Discipline-Based Education Research

   *Basis for pedagogical content knowledge*

2. Research-Based Methods in Teacher Preparation

   *Examples: separate courses for K-6 and 7-12 teachers*

3. Projects with "Physics Teacher Education Coalition"

   *University-based program to improve preparation of physics and physical-science teachers*

# Discipline-Based
# Science and Math Education Research

- Research on the teaching and learning of science and mathematics, at both the K-12 and the college and university level;
- Carried out by researchers with extensive training in math or a specific science discipline;
- Focused on subject-specific learning issues and development of research-based curricular materials and instructional methods.

# Role of Discipline-Based Science and Math Educators

- Carry out in-depth investigations of student thinking in specific disciplines
  - provide basis for “pedagogical content knowledge”
- Develop and assess courses and curricula
- Advise and mentor pre-service and in-service teachers

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# Progress in Teacher Preparation

*"Teachers teach as they have been taught"*

- Advances in research-based science education have motivated changes in teacher preparation (and development) programs.
- There is an increasing focus on research-based instructional methods and curricula, emphasizing "active-engagement" inquiry-based learning.
- **Examples:** *Physics by Inquiry* curriculum (Univ. Washington); Modeling Workshops (Arizona State U.)

# *Example:*
# Course for Pre-service High-School Teachers

- Course for students planning to teach high-school physics (at Iowa State University)
  - includes pre-service and in-service teachers, students with and without B.A., diverse majors
- Reading and discussion of physics education research literature
- In-class instruction using research-based curricular materials (guided by course instructor)
- Students prepare and deliver own lesson
  - model on research-based instructional materials
  - develop activity sheets and “teachers’ guide”

# Research-Based Instruction

- Recognize and address students' pre-instruction "knowledge state" and learning tendencies, including:
  - subject-specific learning difficulties
  - potentially productive ideas and intuitions
  - student learning behaviors
- Guide students to address learning difficulties through structured problem solving, discussion, and Socratic dialogue

# Research in science and math education suggests that:

- Problem-solving activities with rapid feedback yield improved learning gains
- Eliciting and addressing common conceptual difficulties improves learning and retention

# Active-Learning Pedagogy

("*Interactive Engagement*")

- problem-solving activities during class time
  - student group work
  - frequent question-and-answer exchanges

- "*guided-inquiry*" methodology: guide students with leading questions, through structured series of research-based problems

***Goal:* *Guide students to "figure things out for themselves" as much as possible***

# *Example:* Physics Course for Pre-service Elementary Teachers

*In collaboration with Prof. Mani K. Manivannan, and undergraduate student peer instructor Tina N. Tassara*

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# New Inquiry-Based Elementary Physics Course for Nontechnical Students

- One-semester course, met 5 hours per week in lab -- focused on hands-on activities; no formal lecture.
- Targeted especially at education majors, i.e., “teachers in training.”
- Inquiry-based learning: targeted concepts are not told to students before they have worked to “discover” them through group activities.

# Outline of Instructional Method

- **Prediction and Discussion:** Student groups predict outcome of various experiments, and debate their predictions with each other.
- **Experimentation:** Student groups design and implement (with guidance!) methods to test predictions.
- **Analysis and Discussion:** Student groups present results and analysis of their experiments, leading to class-wide discussion and stating of conclusions.

# Example: Force and Motion

*A cart on a low-friction surface is being pulled by a string attached to a spring scale. The velocity of the cart is measured throughout a period of time.*

*The experiment is done three times, and the pulling force is varied each time so that the spring scale reads 1 N, 2 N, and 3 N for trials #1, #2, and #3. (The mass of the cart is kept the same for each trial.)*

*On the graph below, sketch the appropriate lines for velocity versus time for the three trials, and label them #1, #2, and #3.*

Pre-instruction Discussion Question

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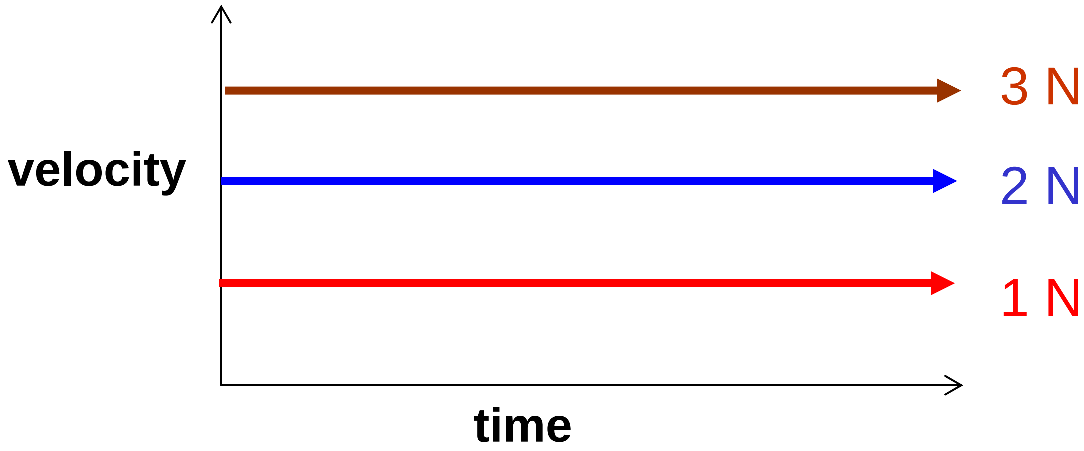
Common student response, pre-instruction



## Sample Class Activity (summary):

*Using the photogate timers, measure the velocity of the low-friction cart as it is pulled along the track.*

*Use the calibrated spring scale to pull the cart with a constant force of 0.20 newtons. Use the data to plot a graph of the cart's velocity as a function of time. Repeat these measurements for a force of 0.10 and 0.30 newtons.*

*Plot the results from these measurements on the same graph (use different colored pencils or different types of fitting lines).*

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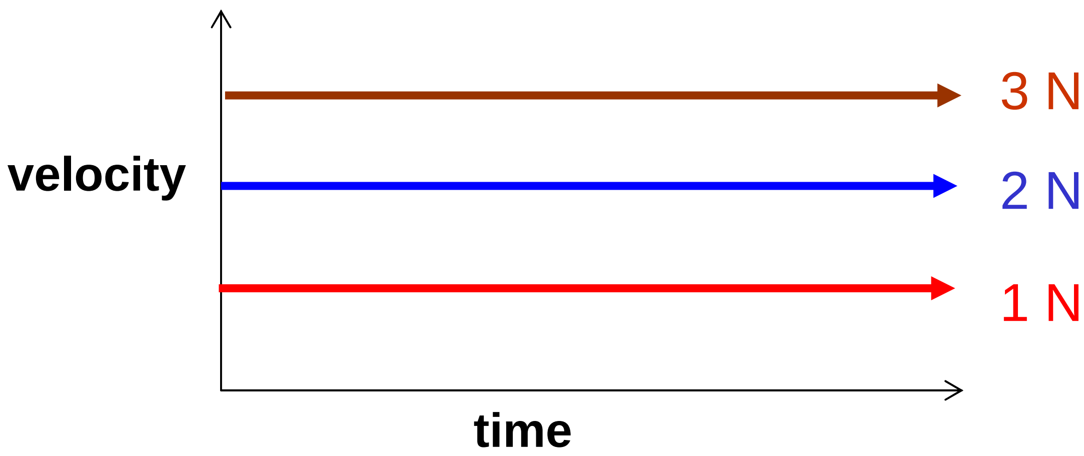

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*The experiment is done three times, and the pulling force is varied each time so that the spring scale reads 0.1 N, 0.2 N, and 0.3 N for trials #1, #2, and #3. (The mass of the cart is kept the same for each trial.)*

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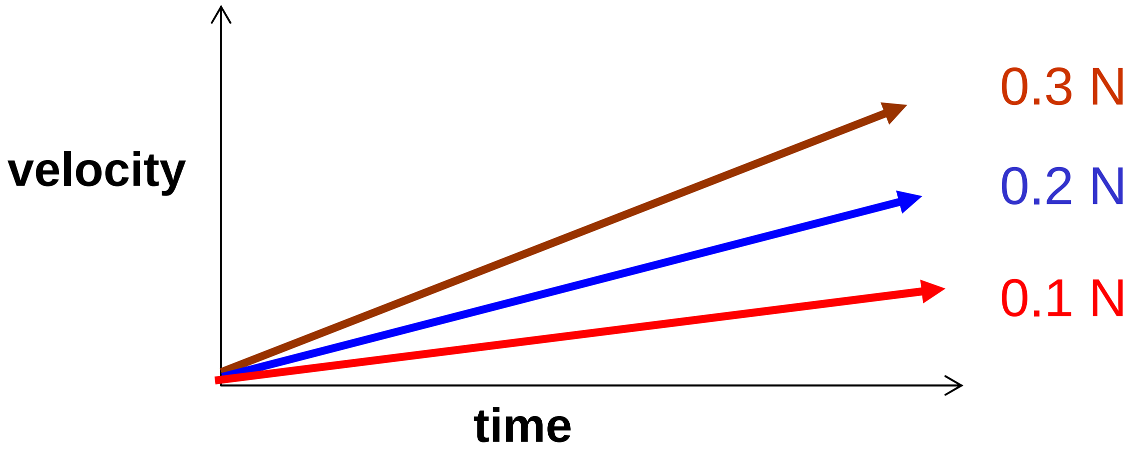
Experimental Result



# What were the goals of instruction?

- Improve students’ conceptual understanding of force and motion, energy, and other topics
- Develop students’ ability to systematically plan, carry out and analyze scientific investigations
- Increase students’ enjoyment and enthusiasm for learning and teaching physics

# Overview of Four Years Experience

- Intensive inquiry-based physics courses may be an enjoyable and rewarding experience for pre-service teachers.
- Effective learning of new physics concepts -- and “unlearning” of misconceptions -- is ***very time intensive.***
- Careful assessment of learning outcomes is <u>essential</u> for realistic appraisal of innovative teaching methods.

# Postscript: Active Learning with Gifted Children

- As the 8th-grade science teacher at a Seattle middle school, I am carrying out research-based activities with two classes (15 students each), 13-14 years old;
- Students have very high levels of verbal and language skills and show subtle and insightful thinking, but span a broad range of mathematical reasoning abilities;
- Even with this highly select group, conceptual and reasoning difficulties emerge which are very similar to those of college students

# Projects with PhysTEC

*"Physics Teacher Education Coalition"*

- Nationwide, NSF-funded program of American Physical Society to develop improved teacher preparation programs in college and university physics departments
- Goals are to produce larger numbers of more effective teachers of physics and physical science for K-12

# Current Projects

- Explore what is meant by “teacher effectiveness” and how it may be assessed
- Investigate and document the roles played by “Teachers in Residence” (experienced K-12 teachers on temporary university assignment with teacher-preparation programs)
- Edit book of scholarly papers on preparation of teachers of physics and physical science

# How can Teacher Effectiveness be Assessed?

- Direct Measures
  - assessment of learning gains and attitudes of teacher’s students
- Indirect measures
  - assessment of teacher’s knowledge, attitudes, and classroom functioning (pre-service and in-service)

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    ***Example:*** *We have assembled packet of content-knowledge assessment materials for classroom use by teacher-education graduates*

# Assessment Methods for Physical Science

- **Conceptual Knowledge**
  - research-based diagnostics (e.g., FCI)
- **Science Process Skills**
  - rubrics to assess experiment-design skill (e.g., Rutgers)
- **Pedagogical Content Knowledge**
  - e.g., assess teachers' interpretation and treatment of students' learning difficulties (e.g., UMaine and Colorado)
- **Science Attitudes**
  - survey instruments such as VASS, CLASS, MPEX
- **Pedagogical Methods**
  - observational rubrics such as RTOP

# Roles of Teachers-in-Residence

- Site visits to observe TIRs carrying out mentorship and supervisory activities
- Document TIRs' interactions with diverse groups of pre-service teachers (K-6, 7-12), e.g.:
  - teaching courses for preservice students
  - classroom observations of pre- and in-service teachers
  - mentorship through meetings with teaching assistants and prospective teachers

## Book of Research Papers on Teacher Preparation

- Problem: Most subject-matter instruction for pre-service teachers occurs in science departments
- There is a shortage of research literature to guide physics departments in teaching of PCK to prospective science teachers
- The book is aimed at addressing this need
  - will be published by American Physical Society and American Association of Physics Teachers

# Summary

- Subject-specific research on student learning lays basis for improving instruction in science and math education.
- "Interactive-engagement" instruction using research-based curricula can improve student learning and effectiveness of teacher preparation.
- Ongoing development and assessment of instructional methods and materials lays the basis for sustained improvements in learning.