Professional development of graduate TAs: The role of physics education research

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Outline

- Introduction: Context
- Need for professional development for TAs
  - Content
  - Pedagogy
- Overview of teaching seminar for TAs
  - Structure
  - Effectiveness
- New investigation: TA ability to assess student understanding
- Preparation of future faculty: A broader perspective

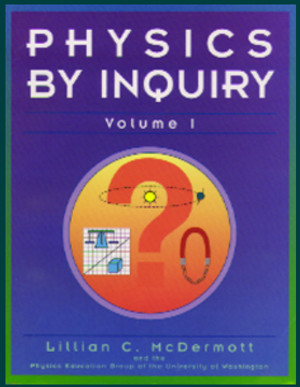
Research-based curriculum development

by the Physics Education Group at the University of Washington

Preparing precollege teachers to teach physics and physical science

- Physics by Inquiry (PbI)

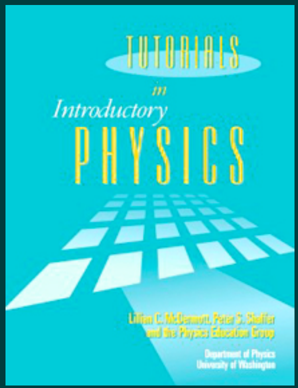
(John Wiley & Sons, Inc., 1996)



Improving student learning in introductory physics

- Tutorials in Introductory Physics

(Prentice Hall, 2002)



Introductory calculus-based sequence

at the University of Washington

Required for physics, chemistry, mathematics, and engineering majors

Components:

- **lecture**
  - meets 3 times per week for ~1 hour
- **laboratory**
  - required
  - ~ 3 hours per week
  - lab reports collected at end of session
- **tutorial**
  - ~ 1 hour per week

Tutorials

Goal

Help students develop *functional understanding* of physics concepts

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Emphasis on

- construction and application of concepts
- development of scientific reasoning ability

Not on

- solution of standard quantitative problems

Tutorial components

- Pretest
  - *administered weekly, usually after lecture instruction*
- Tutorial session (~24 students)
  - *small groups (3-4) work though carefully structured worksheets*
  - *TAs ask questions in a semi-socratic manner*
- Homework
  - *provides additional practice with concepts*
- Post-test (examination question)
  - *(at least one) appears on each course exam*

Traditional TA preparation

Underlying assumptions

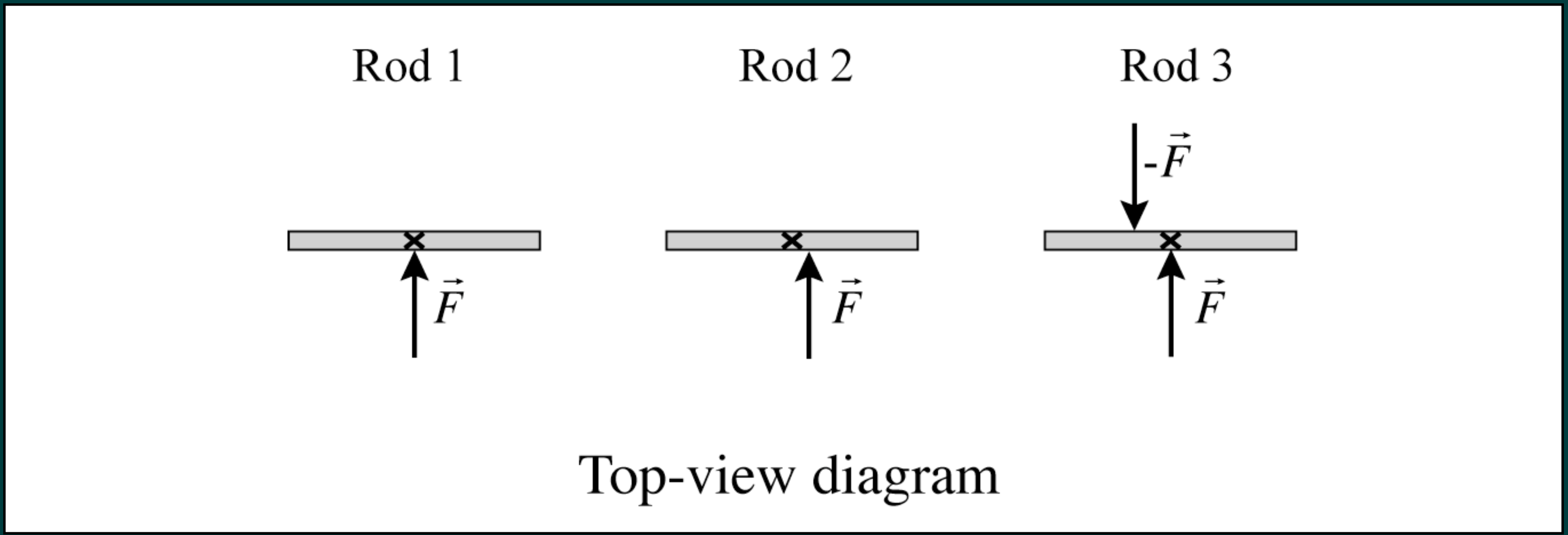
- TAs already possess appropriate content knowledge
- Knowledge of content is sufficient for effective instruction

Emphasis on

- Logistics of implementation— not on physics content
- “Challenging aspects” of materials

Pretest: Dynamics of rigid bodies

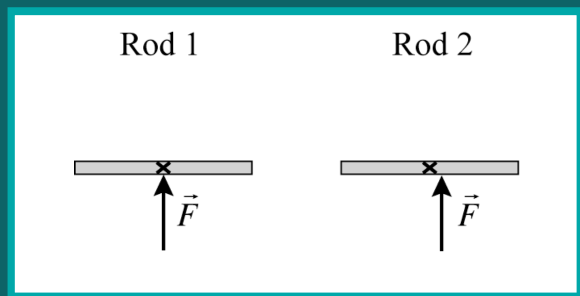
Three identical rods are at rest on a flat, frictionless ice rink. Forces of equal magnitude are exerted on different points on the rods as shown. The “x” indicates the location of each rod’s center of mass.



At the instant shown, rank, from largest to smallest, the magnitudes of the accelerations of the centers of mass of the rods. Explain.

Pretest results: Dynamics of rigid bodies

TAs in Teaching Seminar

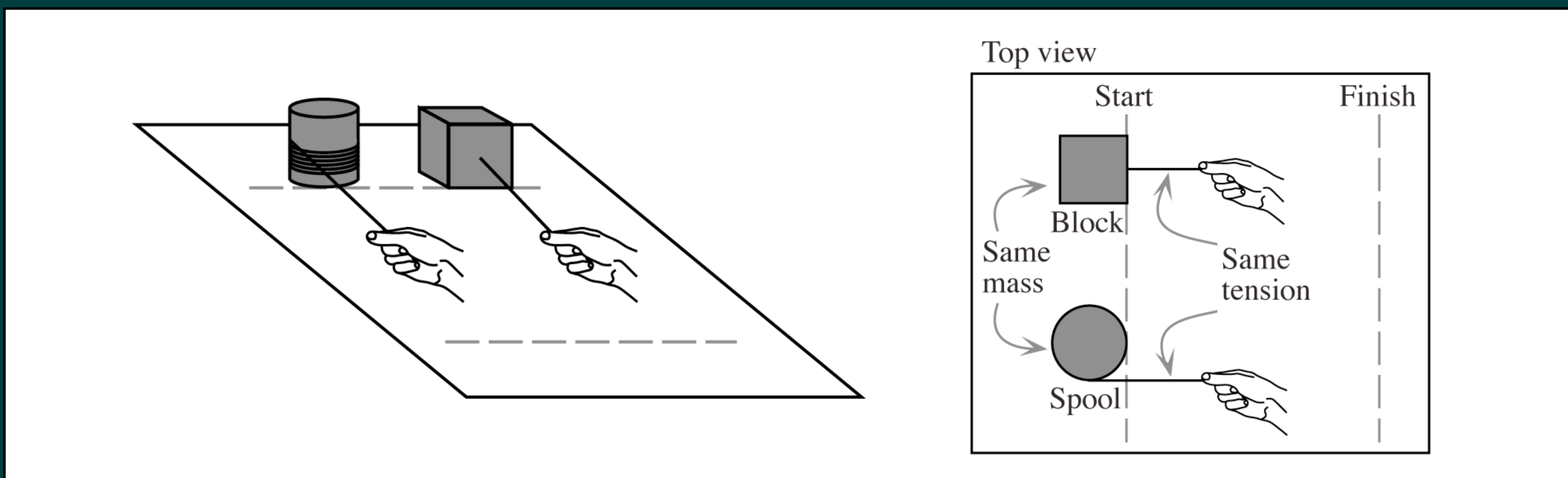
	% of responses
	**Graduate & undergraduate TAs (N = 39)**
$a_{cm1} = a_{cm2} > a_{cm3}$ **(correct)**	30%
Undergraduates in intro calc-based course (N ≈ 655): 5% correct	

"Rod 1 has the force applied at the center of mass, while rod 2 is off center, a [part of the] force is accelerating the center."

More than half of the TAs gave an a_{cm} ranking consistent with location-based force reasoning.

Pretest: Dynamics of rigid bodies

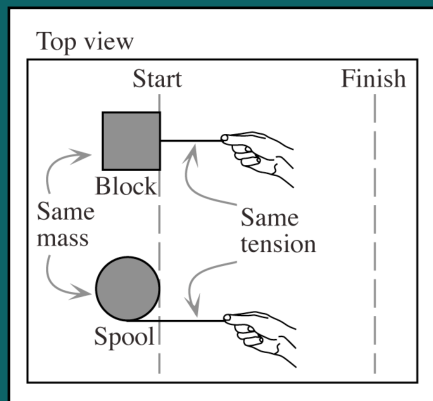
A block and a spool are each pulled across a level, frictionless surface by a massless string. The block and the spool have the same mass. The strings are pulled with the same constant tension and start pulling at the same time.



Will the spool cross the finish line *before, after,* or *at the same instant as* the block?

Pretest results: Dynamics of rigid bodies

TAs in Teaching Seminar

	**% of responses** **Graduate & undergraduate TAs (N = 65)**
Spool rotates and crosses *at same instant* as block (correct)	40%

Undergraduates in intro calc-based course (N = 324): 5% correct

"The spool will cross after the block, since its (linear) acceleration is less. Some of the work goes into rotational KE, rather than all translational like the block."

More than one-third of the TAs explicitly used incorrect work and energy arguments.

Certain conceptual difficulties are not overcome by traditional instruction

Advanced study may not lead to improved understanding of basic topics in introductory physics

It is imperative that such difficulties are addressed explicitly in TA preparation

TAs and other future faculty require special preparation in physics content

Traditional physics instruction

- Lecture mode
- Top-down presentation
- Theoretical perspective
- Emphasis on formalism — not on scientific reasoning
- Large amount of content, rapid pace
  (*e.g.,* introductory course)

Most instructors teach as they were taught

Instructors need to go through the same learning process as their students

TAs and other future faculty require special preparation in instructional method

K. M. Koenig, R. J. Endorf, and G. A. Braun, "Effectiveness of different tutorial recitation teaching methods and its implication for TA training," *Phys. Rev. ST Phys. Educ. Res.* 3, 010104 (2007).

Physics 501-2-3: Tutorials in teaching physics

- Academic year teaching seminar *(3 quarters in length, meets weekly)*
- Required by the physics department for all TAs (regardless of assignment)
- Includes concurrent teaching assignment in 1 tutorial section for introductory calculus-based physics course
- Focuses on introductory physics (including mechanics, electricity & magnetism, and waves & optics)

Teaching seminar: Overview

- Pretest
- Lecture status
- Tutorial (in small groups — one experienced TA per table)
    - Discussion of how to elicit and address potential student difficulties via questioning
      (typically initiated and/or modeled by experienced TAs)
- Review and discussion of student pretest responses
    - Identification of specific difficulties
    - Overview of results
    - Reflection on how difficulties are addressed by tutorial

Review of student pretest responses provides:

- insight into student understanding of material
- opportunity to reflect on *specific* student difficulties
- incentive to listen more carefully to student comments
- evidence of ineffectiveness of traditional instruction (lecturing)

Characteristics that support effective TA preparation

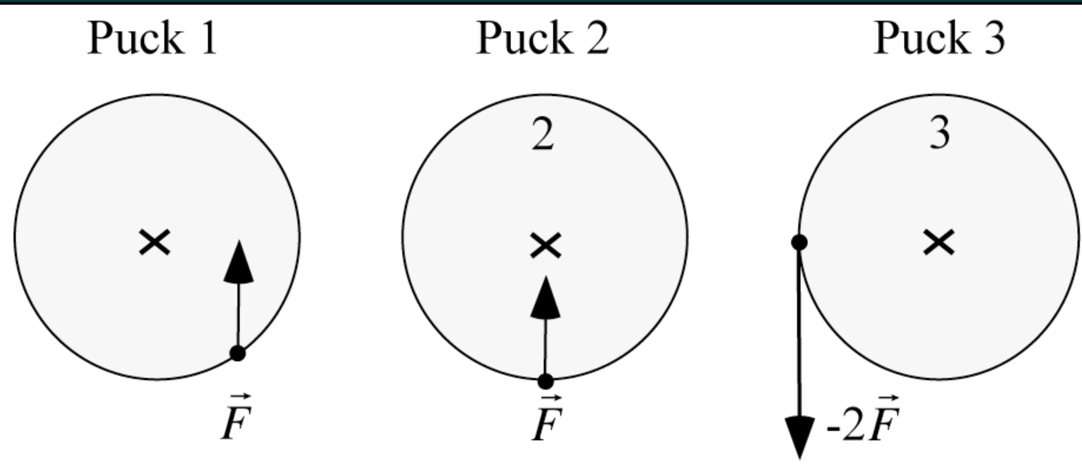
1) “Safe” environment (particularly relevant for first year graduate students)

3) Opportunity to work through materials as learners

4) Framework allowing TAs to examine student understanding for themselves

Post-test: Dynamics of rigid bodies

Three identical circular pucks are at rest on a flat, frictionless ice rink. Forces of magnitudes *F* or 2*F* are exerted at different points along each puck's rim as shown. The "x" indicates the location of each puck's center of mass.

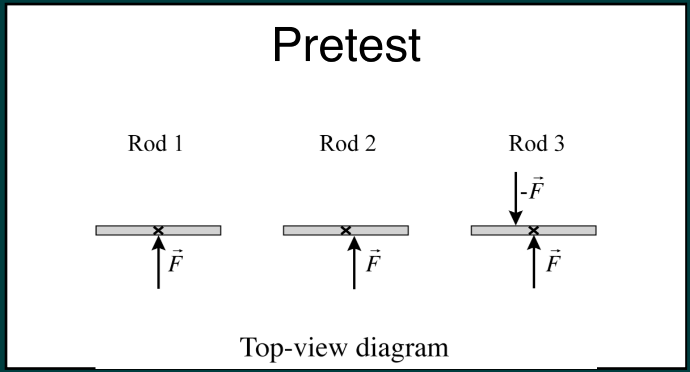


Top-view diagram

At the instant shown, rank, from largest to smallest, the magnitudes of the accelerations of the centers of mass of the pucks. Explain.

Results: Dynamics of rigid bodies

(Before and after tutorial instruction)



Ranking: magnitudes of a_{cm}	Graduate & undergraduate TAs		Undergraduates in introductory calculus-based physics	
	Pretest (N = 39)	Post-test (N = 52)	Pretest (N ≈ 655)	Post-test (N = 165)
% correct	30%		5%	

For most topics, TA post-test performance is typically near 100%*

e.g.,* T. O'Brien Pride, S. Vokos, and L. C. McDermott, *Am. J. Phys.* **66 147-157 (1998).

Extension: Investigation of TA ability to assess student understanding

Motivation

TAs and (future) faculty need to:

- make reasonable inferences about student understanding on the basis of written and verbal responses while grading and teaching
- recognize limitations of certain questions in providing insight into student understanding

Questions for research

- To what extent are TAs able to make these judgments?
- Is there a significant change in the TAs' abilities in these areas over the course of the three-quarter teaching seminar?

Pretest: Assessment of student understanding of dynamics of rigid bodies

TAs examine student responses to a two-part pretest on dynamics of rigid bodies.

A different student's response was given for each part.

For each part, TAs were asked:

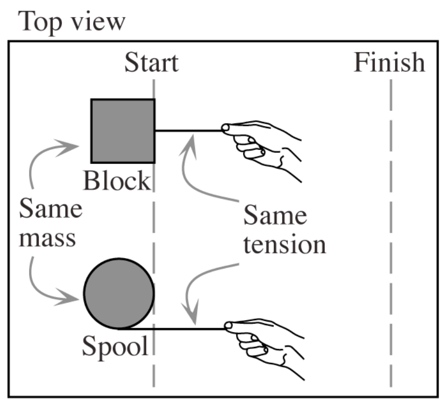
- Is this student's response correct?
- Estimate this student's level of understanding
- Identify two follow-up questions to help deepen your insight

Pretest: Assessment of student understanding of dynamics of rigid bodies

Part A

a. Will the spool begin to rotate? Explain.

Yes - torque is applied to spool



N = 22

Average estimate of student understanding: 2.9

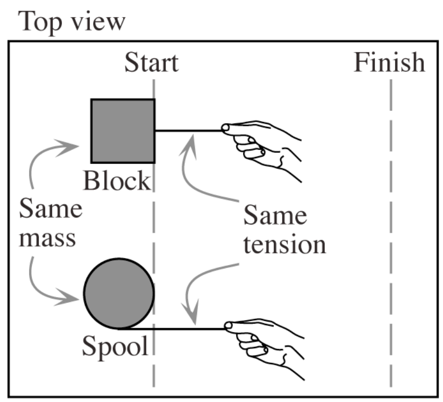
TAs given a scale of 0 to 4, with 0 representing no understanding and 4 representing very good understanding

Pretest: Assessment of student understanding of dynamics of rigid bodies

Part A: TA response

a. Will the spool begin to rotate? Explain.

Yes – torque is applied to spool



"2, possibly 3. The student does not make any consideration for where the force is applied, direction of rotation, or where they are considering the torques about."

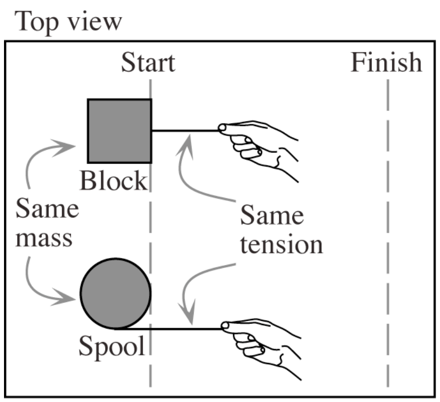
Several of the TA responses reflected careful assessment

Pretest: Assessment of student understanding of dynamics of rigid bodies

Part A: TA performance

a. Will the spool begin to rotate? Explain.

Yes - torque is applied to spool



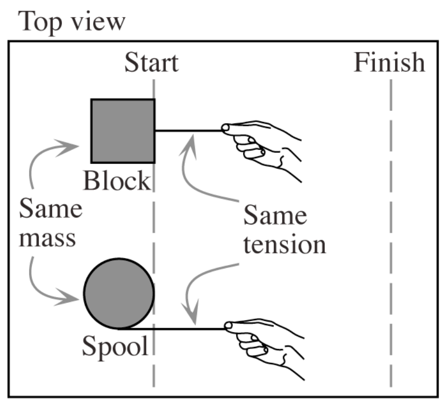
10-25% of TAs gave rankings that could not be justified on the basis of written student response.

Pretest: Assessment of student understanding of dynamics of rigid bodies

Part A: Less careful TA assessments

a. Will the spool begin to rotate? Explain.

Yes - torque is applied to spool



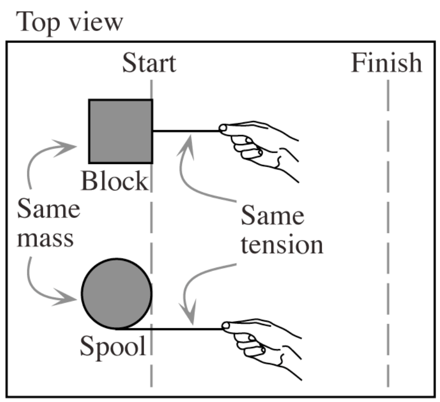
"4… can't think of anything wrong…"

"4… understands that forces offset from center will cause torque and that torque causes rotation."

Pretest: Assessment of student understanding of dynamics of rigid bodies

Part B

b. Will the spool cross the finish line *before, after,* or *at the same instant as* the block? Explain.



After – all energy gained by block is translational K, some energy gained by spool is rotational K, both gain same amount of energy → spool gains translational K at slower rate

TA responses: Assessment pretest

Responses containing evidence for changed answers (15%)

- Is this student's response to part b correct? Explain.

~~No. F=ma Fext is the same => a must be the same~~
~~↑ m is the same~~

Yes.

- Is this student's response to part b correct? Explain.

~~No. They should reach the finish line at the same time~~

Yes, ~~then~~ his logic seems correct

Such responses highlight the challenges faced by TAs when dealing with incorrect student reasoning

Knowledge of physics content and instructional method is not enough

TAs require special preparation in assessing student understanding and practice in identifying and responding to incorrect lines of reasoning

A broader perspective: Physics education reform

TA preparation plays a critical role in reform efforts because it can help future faculty:

- discover that students must be actively engaged in learning physics
- recognize that student difficulties must be addressed explicitly
- reflect on particular instructional strategies
- gain experience in assessing student understanding (*via written and verbal responses*)
- become familiar with a particular set of research-based instructional materials (dissemination)