Ideas from Physics Education Research to help you change your classroom

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Ideas from Physics Education Research to help you think about how to change your classroom

48th Stirling Physics Teachers Meeting

25 May 2023
Stirling Court Hotel, Stirling, Scotland

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Classroom Focused
Generic
Physics Specific
Research/Theoretical
Working Memory & Learning
A Practical Guide for Teachers
Susan E. Gathercole & Tracy Packiam Alloway
EMBEDDED formative assessment
DYLAN WILIAM
THE EARLY CAREER FRAMEWORK HANDBOOK
JASPER GREEN
Powerful Ideas of SCIENCE and How to Teach Them
FIVE EASY LESSONS
Strategies for Successful Physics Teaching
RANDALL D. KNIGHT
The Association for Science Education
Teaching Secondary Physics
Third Edition
HODDER EDUCATION
The Big Ideas in Physics and How to Teach Them
BEN ROGERS
PHYSICS BY INQUIRY
Volume I
Lillian C. McDermott
2ND EDITION
Learning Theories in Childhood
COLETTE GRAY AND SEAN MACBLAIN
Edited by KNUD ILLERIS
CONTEMPORARY THEORIES OF LEARNING
Learning Theorists . . . In Their Own Words
LINKING PRACTICE AND THEORY
The Pedagogy of Realistic Teacher Education
FRED A. J. KORTHAGEN
in cooperation with
Jos Kessels
Bob Koster
Bram Lagerwerf
Theo Wubbels
INTERNATIONAL ACADEMY OF EDUCATION
INTERNATIONAL BUREAU OF EDUCATION
Principles of instruction
by Barak Rosenshine
NEW DIRECTIONS IN MATHEMATICS AND SCIENCE EDUCATION
Science Education
An International Course Companion
Keith S. Taber and Ben Akpan (Eds.)
SensePublishers
EDWARD F. REDISH
TEACHING PHYSICS
WITH THE PHYSICS SUITE
Thinking in Physics
The pleasure of reasoning and understanding
Laurence Viennot
Springer
Thinking Physics for Teaching
Edited by
Carlo Bernardini, Carlo Tarsitani, and Matilde Vicentini

What is PER?


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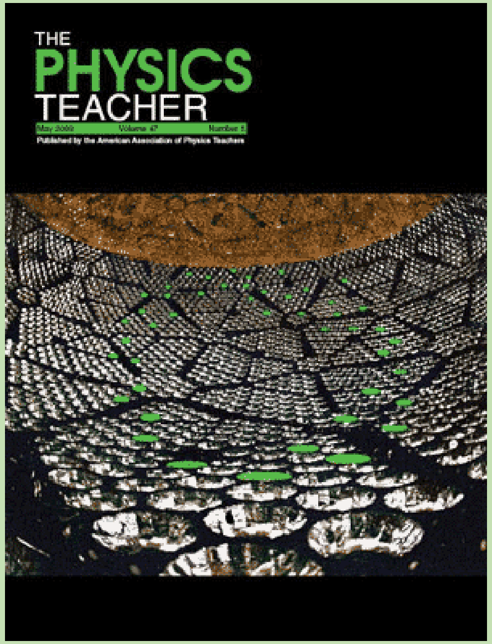
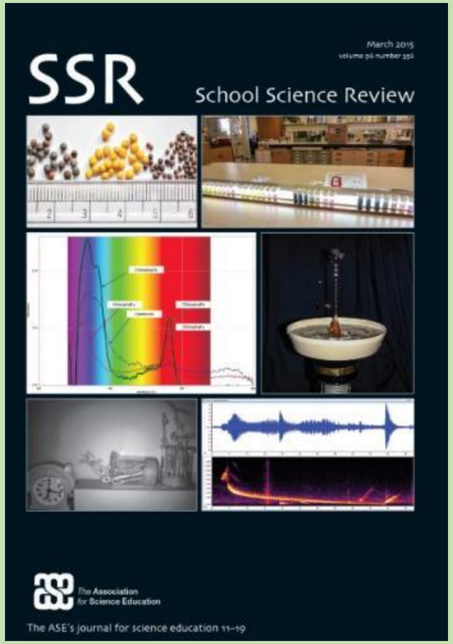
IJSE
International Journal of Science Education


Volume 50 Number 6 November 2015
ISSN 0031-9120
Physics education
iopscience.org/physed
The 'Rim of Fire'
Calculating the brightness of a total lunar eclipse
Papers: Spinning marbles, Bouncing balls Frontline: Swinging liquids
IOP Publishing


THE PHYSICS TEACHER
Published by the American Association of Physics Teachers


SSR
School Science Review
March 2015
The Association for Science Education
The ASE's journal for science education 11–19

What research can do for us
(and what it cannot)

Unlikely to tell us

'what is the perfect way to teach x so students will understand it'

Can (and should) help us ask better questions of our own practice and help us make better choices.

And evaluate the success or effectiveness of what we do.

What research can do for us
(and what it cannot)

Some good things to read

Ways of thinking about teaching and learning

Ways of thinking about thinking

Ways of evaluating our teaching and their learning

Questions

Surveys

Thinking About Thinking

Curriculum Development

PER Heroes I – Lillian McDermott

Oersted Medal Lecture 2001: "Physics Education Research—The Key to Student Learning"

Lillian Christie McDermott
Department of Physics, University of Washington, Seattle, Washington 98195-1560

Research on the learning and teaching of physics is essential for cumulative improvement in physics instruction. Pursuing this goal through systematic research is efficient and greatly increases the likelihood that innovations will be effective beyond a particular instructor or institutional setting. The perspective taken is that teaching is a science as well as an art. Research conducted by physicists who are actively engaged in teaching can be the key to setting high (yet realistic) standards, to helping students meet expectations, and to assessing the extent to which real learning takes place.
[DOI: 10.1119/1.1389280]

American Journal of Physics **69**, 1127 (2001)
https://doi.org/10.1119/1.1389280

Some research based generalisations about Learning and Teaching

Facility in solving standard quantitative problems is not an adequate criterion for functional understanding.

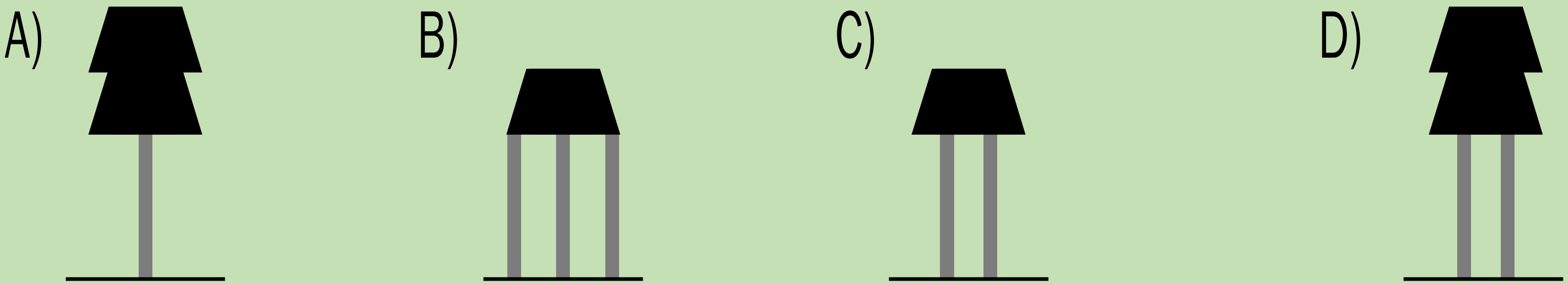
Questions that require qualitative reasoning and verbal explanation are essential for assessing student learning and are an effective strategy for helping students learn.

Challenge students with qualitative questions that cannot be answered through memorization, insist that they do the necessary reasoning by not supplying them with answers.

Questions

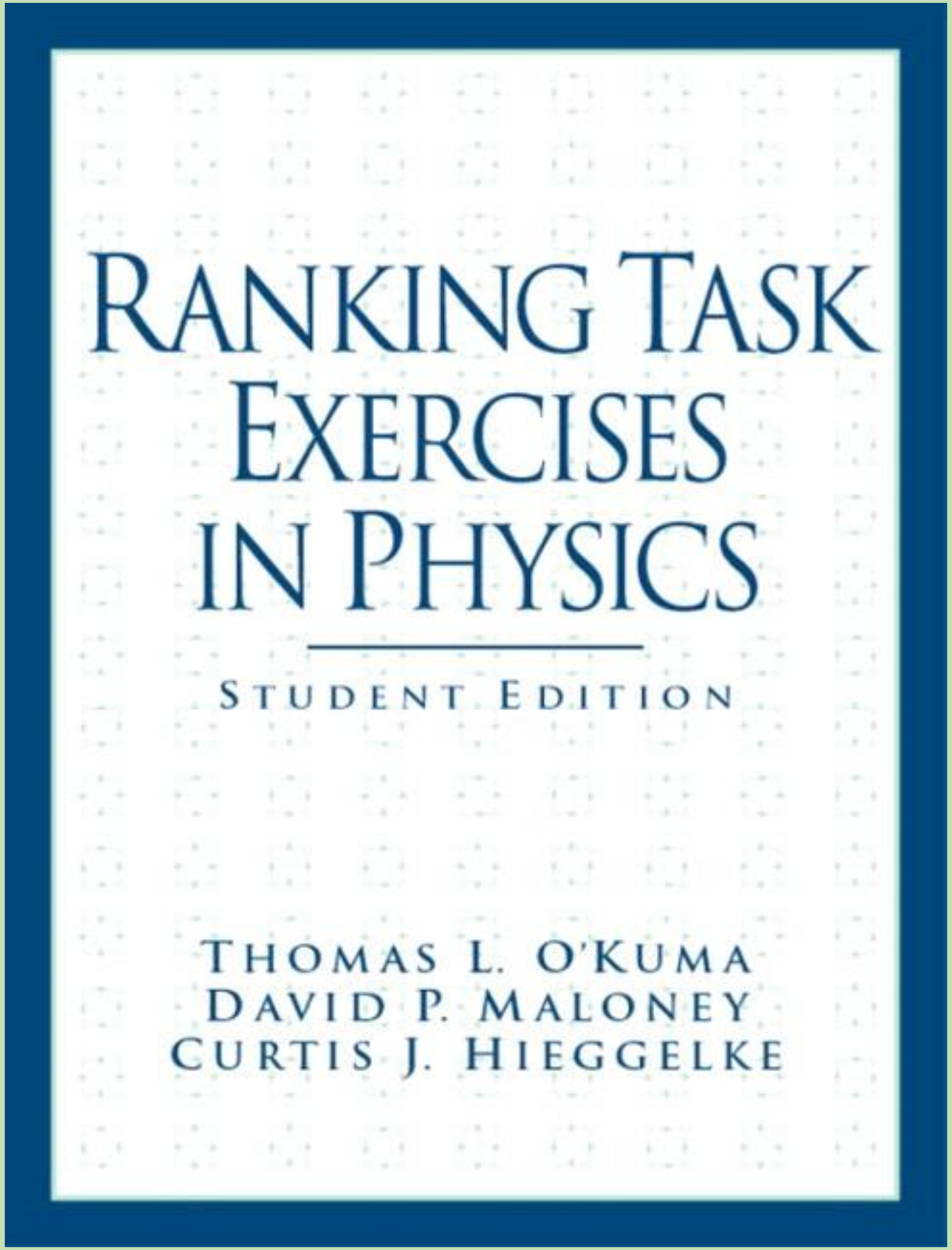
Ranking Tasks

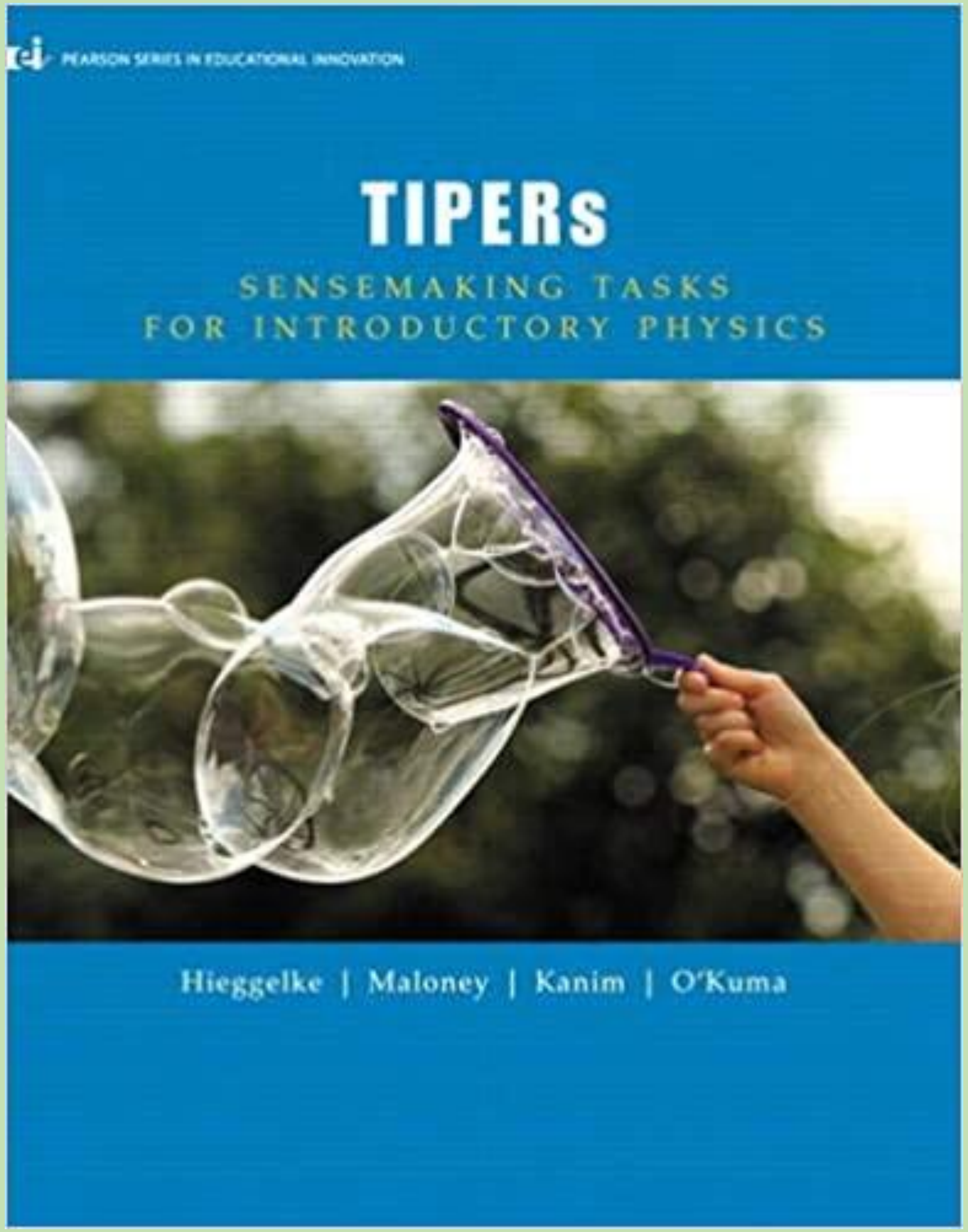
Black masses of equal weight are placed on grey pillars of the same cross sectional area. Rank the situations by the pressure exerted on the surface on which they stand. Indicate your level of certainty (10= completely sure / 0= complete guess).



Highest pressure | | | | | Lowest pressure

Certainty: /10

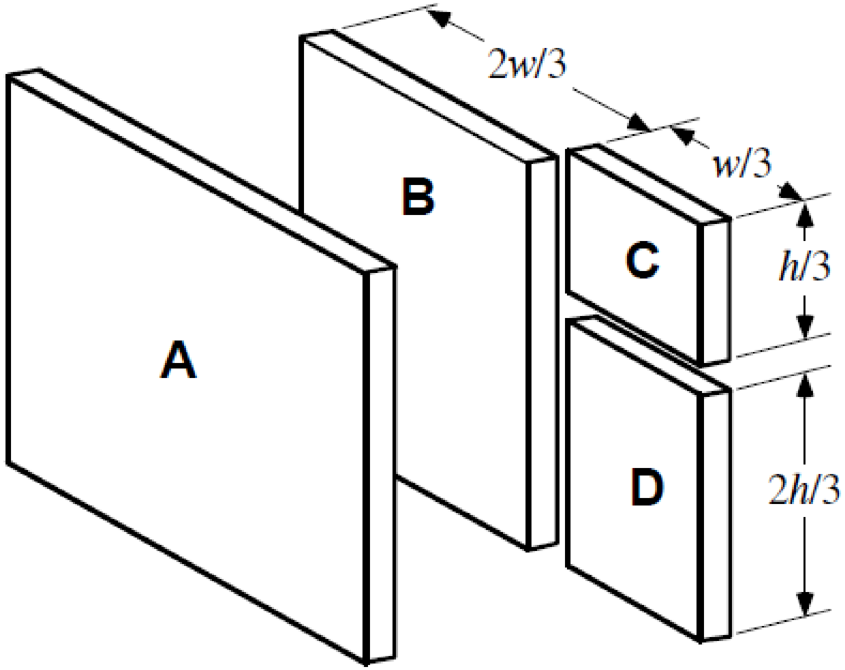

RANKING TASK
EXERCISES
IN PHYSICS
STUDENT EDITION
THOMAS L. O'KUMA
DAVID P. MALONEY
CURTIS J. HIEGGELKE


PEARSON SERIES IN EDUCATIONAL INNOVATION
TIPERs
SENSEMAKING TASKS
FOR INTRODUCTORY PHYSICS
Hieggelke | Maloney | Kanim | O'Kuma

C1 DENSITY

C1-RT01: CUTTING UP A BLOCK—DENSITY

A block of material (labeled A in the diagram) with a width *w*, height *h*, and thickness *t* has a mass of M_o distributed uniformly throughout its volume. The block is then cut into three pieces, B, C, and D, as shown.

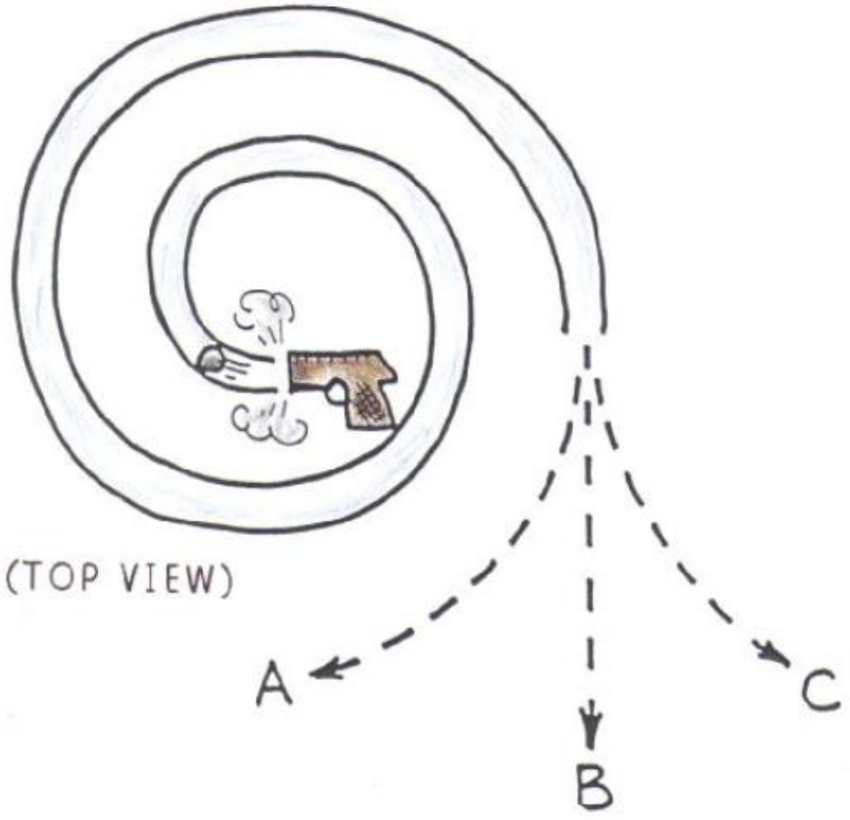


Rank the density of the original block A, piece B, piece C, and piece D.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

NEXT-TIME QUESTION

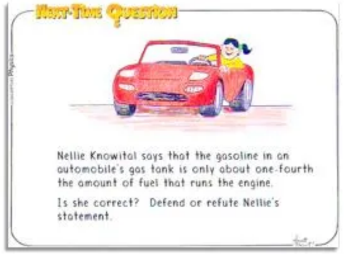


When the pellet fired into the spiral tube emerges, which path will it follow? (Neglect gravity.)

Next-Time Questions

These Next-Time Questions are for you!

Next-Time Questions are favorite insightful questions I have asked my students over my teaching career. I have embellished them with cartoons to catch interest. Their intention is to elicit student thinking. My use of them was posting several in a glass case outside my lecture hall—without answers. The wait-time for answers was one week. I could have called them Next-Week Questions, which would have been more appropriate.



Most of these have been published over the years as Figuring Physics in The Physics Teacher magazine. They have also been in ancillaries to my Conceptual Physics textbooks, and physical science textbooks as well. My hope is that teachers will pose the questions, and withhold answers to "next time," which could be as early as the next class meeting. Their educational value is the long wait time!

Although these are copyrighted, teachers are free to download any or all of them for sharing with their students. But please, DO NOT show the answers to these in the same class period where the question is posed!!! Do not use these as quickie quizzes with short wait times in your lecture. Taking this easy and careless route misses your opportunity for increased student learning to occur. In my experience students have benefited by the discussions, and sometimes arguments, about answers to many of these questions. When they'd ask for early "official" answers, I'd tell them to confer with friends. When friends weren't helpful, I'd suggest they seek new friends! It is in such discussions that learning takes place.

You may wish to project these Next-Time Questions rather than post them. One or two projected at the end of a class session is fine. The answer is given "next time" the class meets—or at some interval where wait time is at least a day.

These Next-Time Questions are the outcome of my long and wonderful teaching career. They're yours at the click of a mouse. Please use them as I suggest.

~ Paul Hewitt

https://www.arborsci.com/pages/next-time-questions

Concept Inventories

18. The following figure shows a boy swinging, starting at a point higher than P. Consider the following distinct forces:

A. a downward force of gravity.

B. a force exerted by the rope pointing from P to O.

C. a force in the direction of the boy's motion.

D. a force pointing from O to P.

Which of the above forces is (are) acting on the boy when he is at position P?

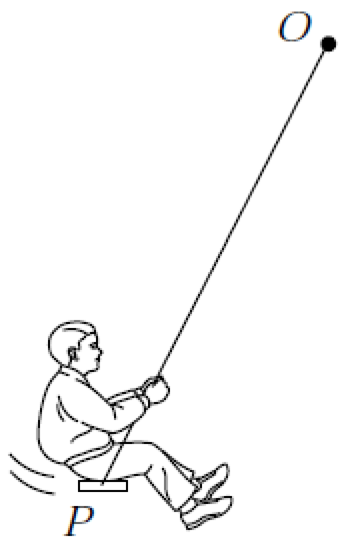
___ 1. A only

___ 2. A and B

___ 3. A and C

___ 4. A, B, and C

___ 5. A, C, and D



Resource Letter RBAI-1: Research-Based Assessment Instruments in Physics and Astronomy

Adrian Madsen and Sarah B. McKagan
American Association of Physics Teachers, College Park, Maryland 20740

Eleanor C. Sayre
Department of Physics, Kansas State University, Manhattan, Kansas 66506

(Received 1 May 2016; accepted 30 January 2017)

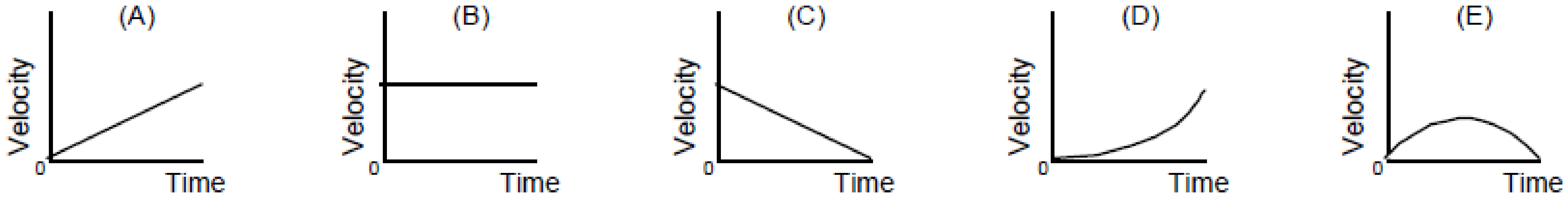
This resource letter provides a guide to Research-Based Assessment Instruments (RBAIs) of physics and astronomy content. These are standardized assessments that were rigorously developed and revised using student ideas and interviews, expert input, and statistical analyses. RBAIs have had a major impact on physics and astronomy education reform by providing a universal and convincing measure of student understanding that instructors can use to assess and improve the effectiveness of their teaching. In this resource letter, we present an overview of all content RBAIs in physics and astronomy by topic, research validation, instructional level, format, and themes, to help faculty find the best assessment for their course. More details about each RBAI available in physics and astronomy are available at PhysPort: physport.org/assessments.
[http://dx.doi.org/10.1119/1.4977416]

https://doi.org/10.1119/1.4977416

Table III. Introductory mechanics assessments.

Title	Content	Intended population	Research validation	Purpose
Kinematics and forces				
Force Concept Inventory (FCI)	Kinematics, forces: 1D and 2D	Intro college, high school	Gold	To assess students' understanding of the most basic concepts in Newtonian physics using everyday language and common-sense distractors
Force and Motion Conceptual Evaluation (FMCE)	Kinematics, forces: 1D	Intro college, high school	Gold	To assess students' understanding of Newtonian mechanics
Mechanics Baseline Test (MBT)	Kinematics, forces, energy, momentum	Intro college, high school	Bronze	To assess more formal dimensions of basic Newtonian physics
Inventory of Basic Conceptions-Mechanics (IBCM)	Kinematics, forces	Intro college	Silver	To assess the basic threshold of meaningful understanding of Newtonian theory
Test of Understanding of Graphs: Kinematics (TUG-K and TUG-K2)	Kinematics graphs	Intro college, high school (use TUG-K2)	Gold	To assess students' ability to interpret kinematics graphs
Force, Velocity and Acceleration Test (FVA)	Force, velocity, acceleration	Intro college	Bronze	To assess students' understanding of the relationships between force, velocity, and acceleration
Energy				
Energy and Momentum Conceptual Survey (EMCS)	Energy, momentum	Intro college	Gold	To assess conceptual understanding of energy and momentum for standard introductory mechanics courses
Energy Concept Assessment (ECA)	Energy principle, forms of energy, work and heat, absorption & emission	Intro college	Silver	To assess conceptual understanding of students in the matter & interactions (M&I) Mechanics courses

1. Velocity versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest change in position during the interval?



Test of
Understanding
Graphs–
Kinematics *version 2.6*

Welcome to PhysPort, the go-to place for physics faculty to find resources based on physics education research (PER) to support your teaching. **Learn more...**

Teaching
I want to...
- find a new teaching method
- find curricular materials
- train my LAs or TAs
- run a faculty workshop

Assessment
I want to...
- find an assessment
- analyze assessment results
- assess advanced physics content or skills

Troubleshooting
I need help with...
- engaging students
- arguments for skeptical colleagues
- something else

Latest news from PhysPort

Physics and Astronomy Faculty Teaching Institute (FTI): Learn about and register for this intensive professional development workshop June 26-29, 2023 in Washington, D.C.

Free open-source research-based curricula: PhysPort now hosts collections of curricula.

Use our Periscope collection of video lessons in your online LA/TA training class: Contact us for more details.

Find a physics education consultant: Find external evaluators, researchers, writers, editors, and more to help with your project.

Curated collection of free wave and optics resources for your online class: Simulations & models, virtual labs, data analysis tools, video collections, and free during COVID-19.

Featured Expert Recommendations

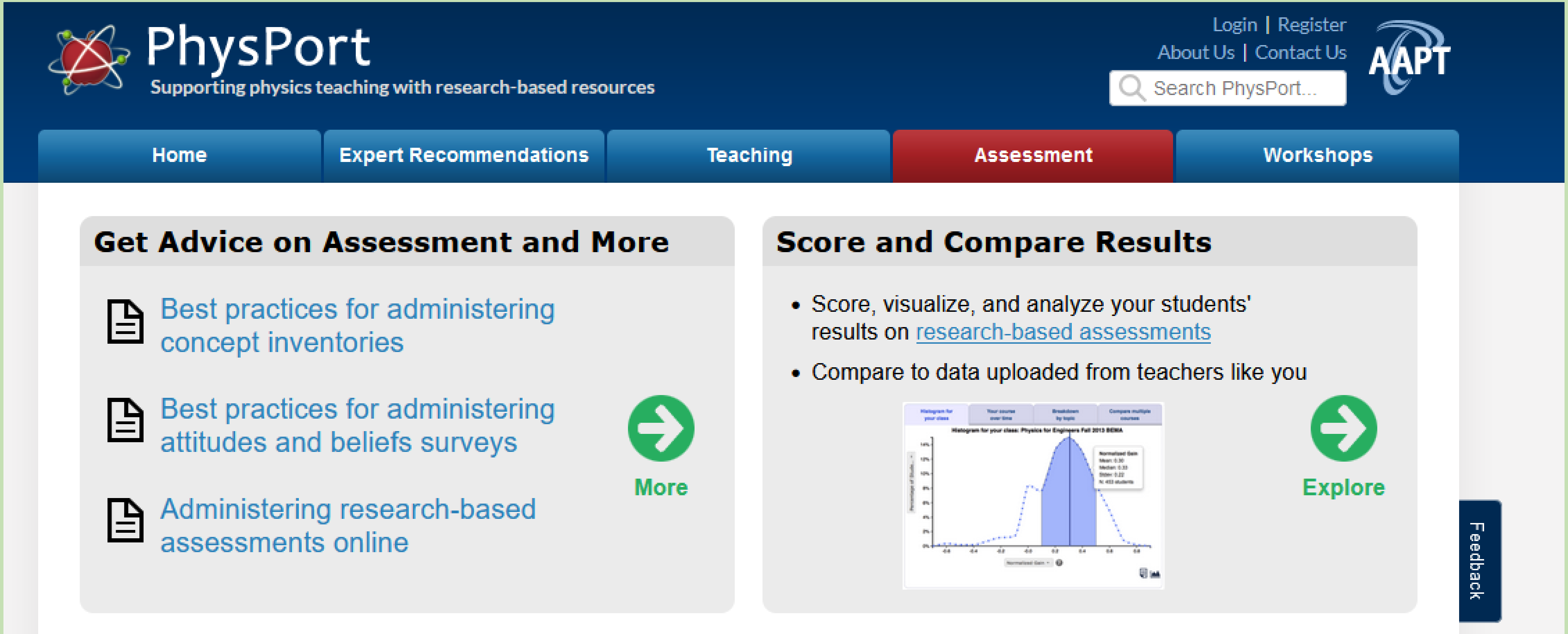
Where can I find good questions to use with clickers or Peer Instruction?

by Sam McKagan, PhysPort director September 26, 2016

Many research-based teaching methods in physics, including Peer Instruction, CAE Think-Pair-Share, Technology Enhanced Formative Assessment, and teaching with clickers, involve having your students discuss and answer multiple-choice conceptual questions. A challenge of using these methods is finding and writing good questions. This recommendation helps you find and write questions for your class.

Peer Instruction, CAE Think-Pair-Share, Technology-Enhanced Formative Assessment, clickers **Read more »**

Feedback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Assessment
Workshops
Get Advice on Assessment and More
Best practices for administering concept inventories
Best practices for administering attitudes and beliefs surveys
Administering research-based assessments online
More
Score and Compare Results
Score, visualize, and analyze your students' results on research-based assessments
Compare to data uploaded from teachers like you
Explore
Feedback

Surveys

Rate the following statements

1=Completely agree ← → 5=Completely disagree

a) A significant problem in learning physics is being able to memorize all the information I need to know.
b) When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.
c) I think about the physics I experience in everyday life.
d) It is useful for me to do lots and lots of problems when learning physics.

Colorado Learning Attitudes towards Science (CLASS)

Statement
1. A significant problem in learning physics is being able to memorize all the information I need to know.
2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.
3. I think about the physics I experience in everyday life.
4. It is useful for me to do lots and lots of problems when learning physics.
5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
6. Knowledge in physics consists of many disconnected topics.
[a]7. As physicists learn more, most physics ideas we use today are likely to be proven wrong.
8. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.
9. I find that reading the text in detail is a good way for me to learn physics.
10. There is usually only one correct approach to solving a physics problem.

PhysPort
Supporting physics teaching with research-based resources

12 Research-Based Assessments
Beliefs / Attitudes

Sort by: Subject

Beliefs / Attitudes

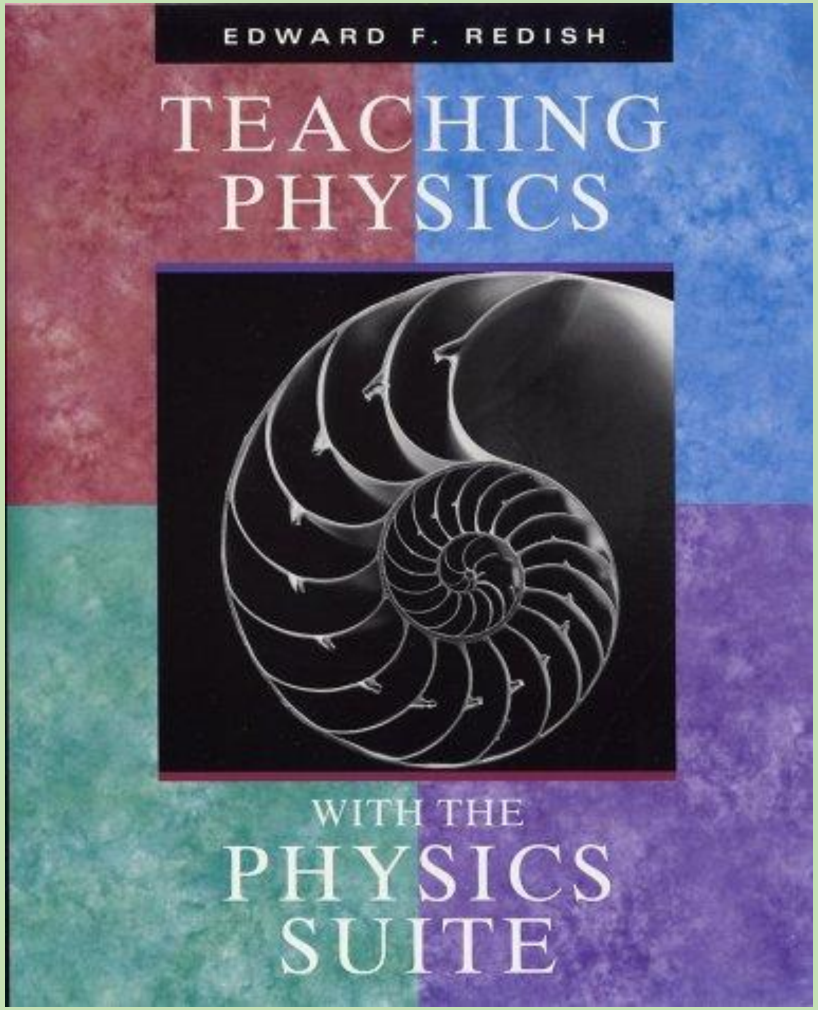
Colorado Learning Attitudes about Science Survey (CLASS)
Beliefs / Attitudes (epistemological beliefs)
Levels: Upper-level, Intermediate, Intro college, High school
Formats: Pre/post, Multiple-choice, Agree/disagree
8-10 min

Maryland Physics Expectations Survey (MPEX)
Beliefs / Attitudes (epistemological beliefs)
Levels: Upper-level, Intermediate, Intro college, High school
Formats: Pre/post, Multiple-choice, Agree/disagree
20-30 min

Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS)
Beliefs / Attitudes (affect, confidence, math-physics-data connection, physics community, uncertainty, troubleshooting, argumentation, experimental design, modeling)
Levels: Upper-level, Intermediate, Intro college
Formats: Pre/post, Multiple-choice, Agree/disagree
15 min

Thinking About Thinking

PER Heroes II – Joe Redish



Oersted Lecture 2013: How should we think about how our students think?

Edward F. Redish
Department of Physics, University of Maryland, College Park, Maryland 20742-4111

(Received 23 August 2013; accepted 18 April 2014)

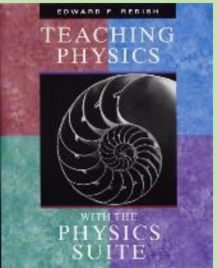
https://doi.org/10.1119/1.4874260

Teaching Physics With The Physics Suite – Edward Redish
http://www2.physics.umd.edu/~redish/Book/

IMPLICATIONS OF THE COGNITIVE MODEL FOR INSTRUCTION: FIVE FOOTHOLD PRINCIPLES

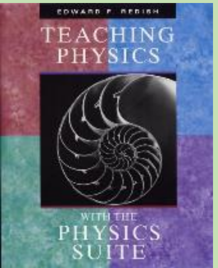
Any model of thinking is necessarily complex. We think about many things in many ways. In order to find ways to see the relevance of these cognitive ideas and to apply them in the context of physics teaching, I have selected five general principles that help us understand what happens in the physics classroom.

1. The constructivism principle
2. The context principle
3. The change principle
4. The individuality principle
5. The social learning principle



Change Principle

It is reasonably easy to learn something that matches or extends and existing scheme, but changing a well established schema substantially is difficulty



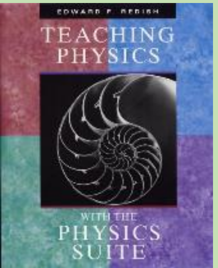
Change Principle

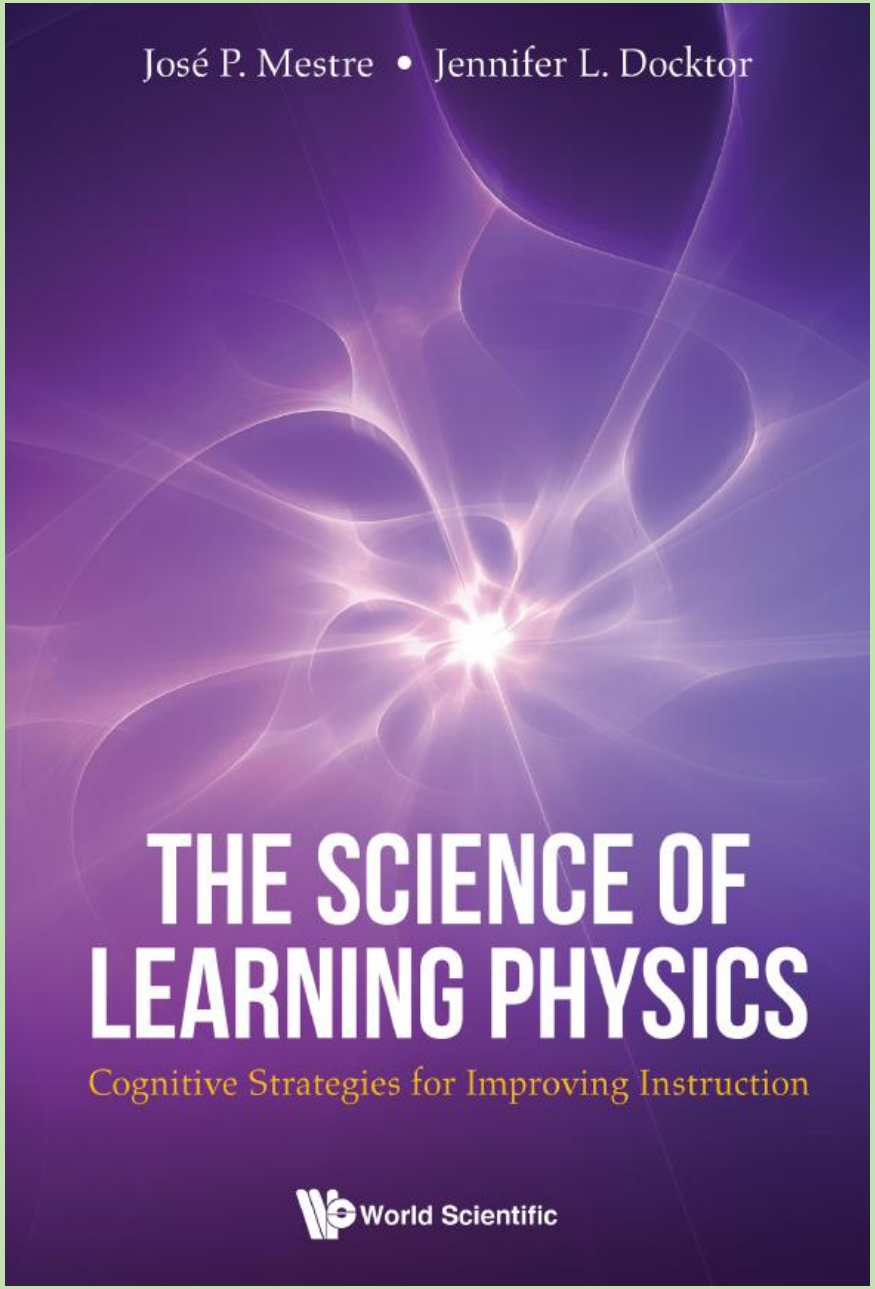
It is very difficult to change an established mental model

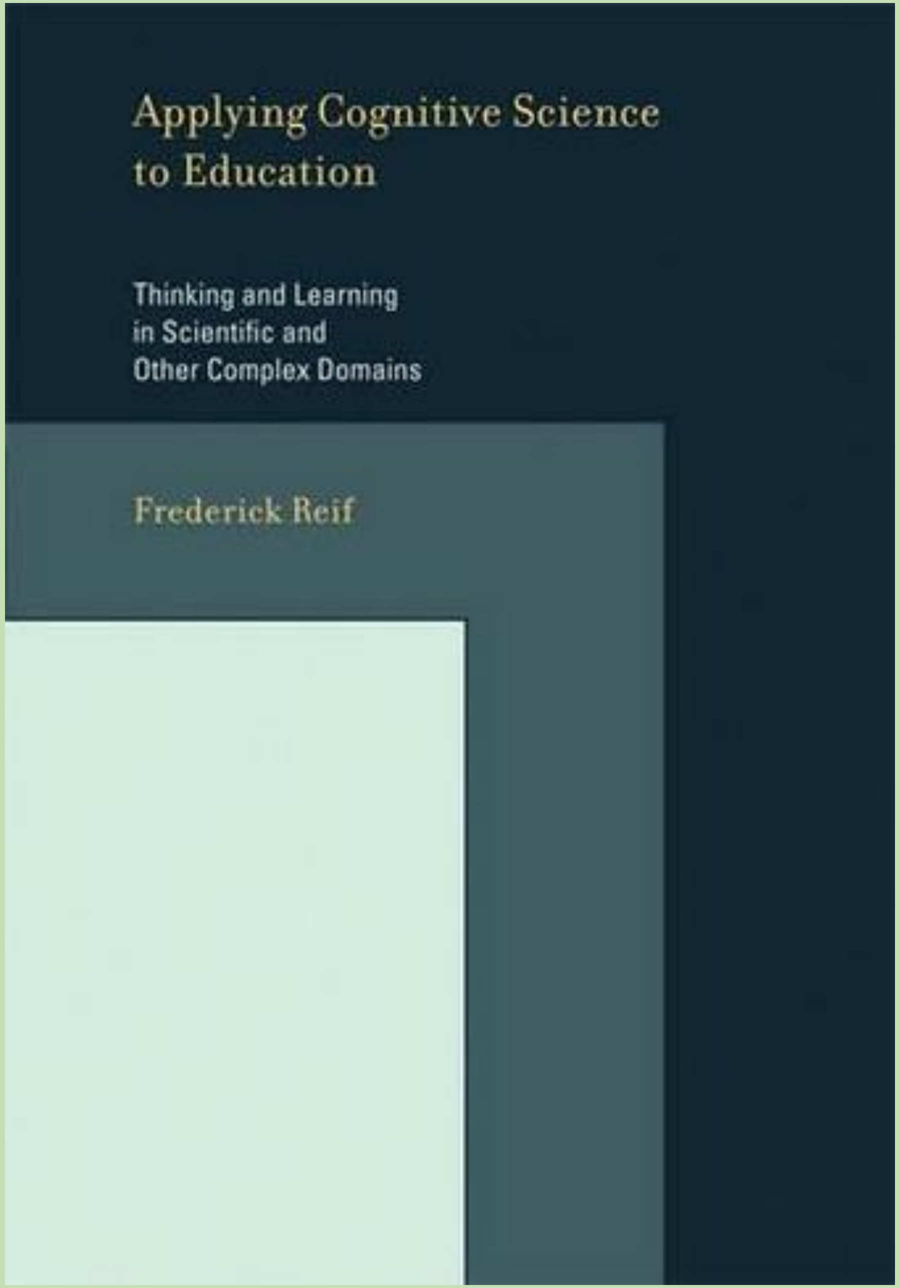
Much of our learning is done by analogy

Good examples are very important

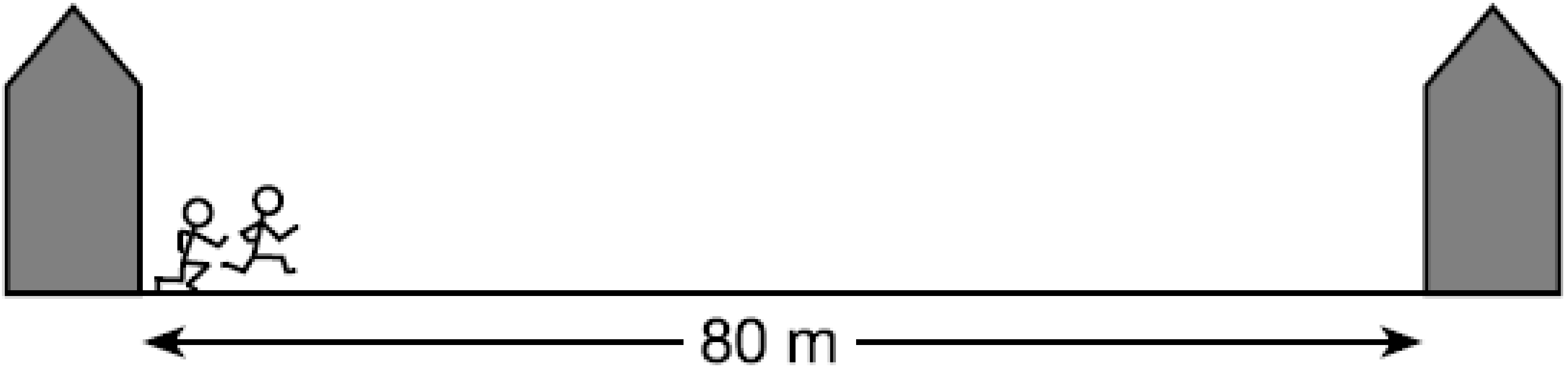
It's hard to learn something that we don't almost already know




José P. Mestre • Jennifer L. Docktor
THE SCIENCE OF LEARNING PHYSICS
Cognitive Strategies for Improving Instruction
World Scientific


Applying Cognitive Science to Education
Thinking and Learning in Scientific and Other Complex Domains
Frederick Reif

Janet and her brother John decided to race along to the end of their street and back again. The street was 80 m long. Janet ran at 2.5 $m\,s^{-1}$ whilst John's speed was 1.5 $m\,s^{-1}$.



Where were they when they passed each other?

How do you approach a physics problem?

Bob Kibble
Moray House Faculty of Education, Edinburgh University, UK

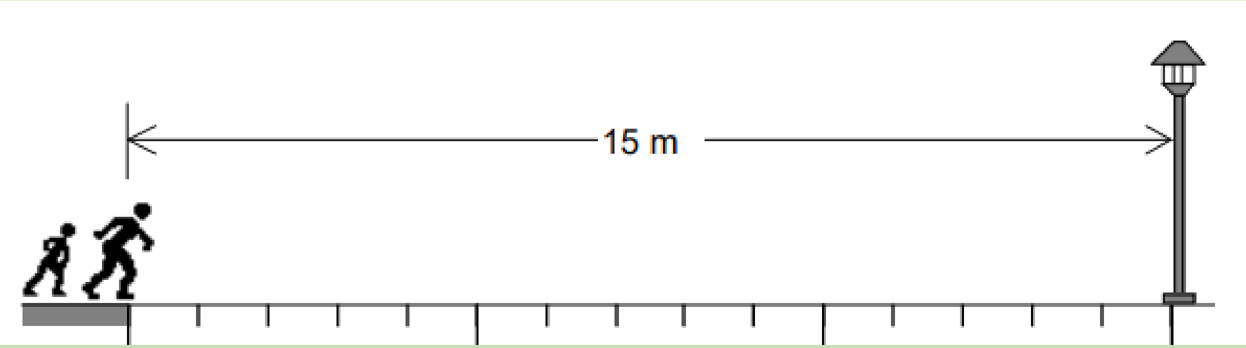
Phys. Educ. **34**(1) January 1999

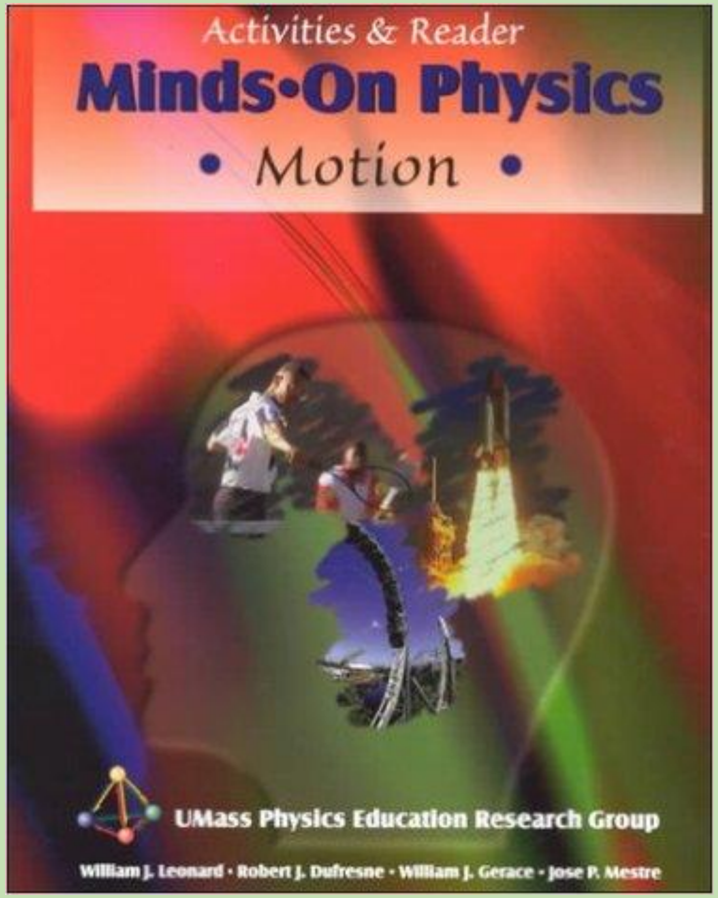
Curriculum Development

Minds•On Physics Activity

16

Solving Constant-Velocity Problems Using Different Methods





METHOD A: Using Strobe Diagrams to Analyze Motion

METHOD B: Using Algebra To Analyze Motion

METHOD C: Using Graphs to Analyze Motion

Reflection

R1. Of the three methods used in this activity…

(a) … which is easiest to work with?

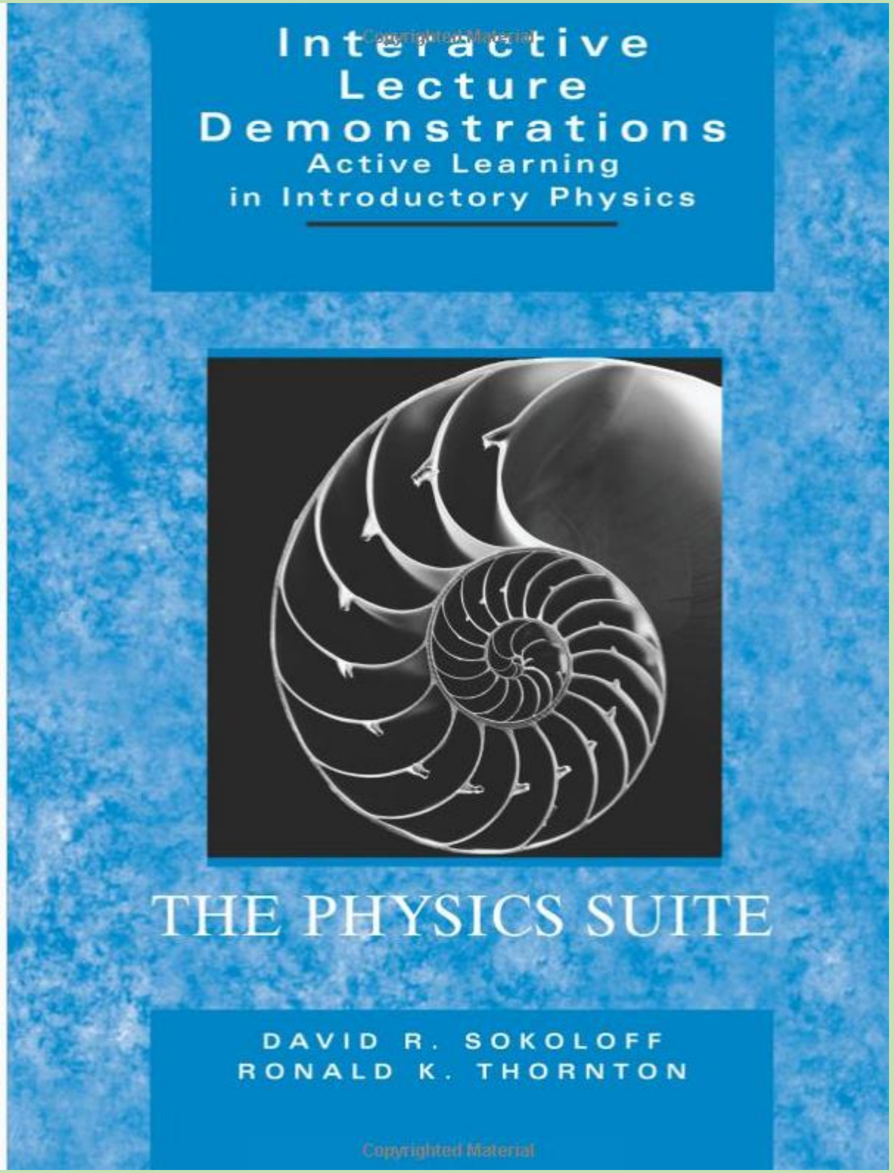
(b) … which contains the most information?

(c) … which would you use to show someone else how to do these problems?

(d) … which would you like to learn better how to use?

(e) … which would you recommend others use to answer these types of questions?

R2. Does the expression "constant velocity" as used in this situation mean that all velocities are the same? If not, how many different velocities were used, and what were they? What does the expression "constant velocity" mean in this context?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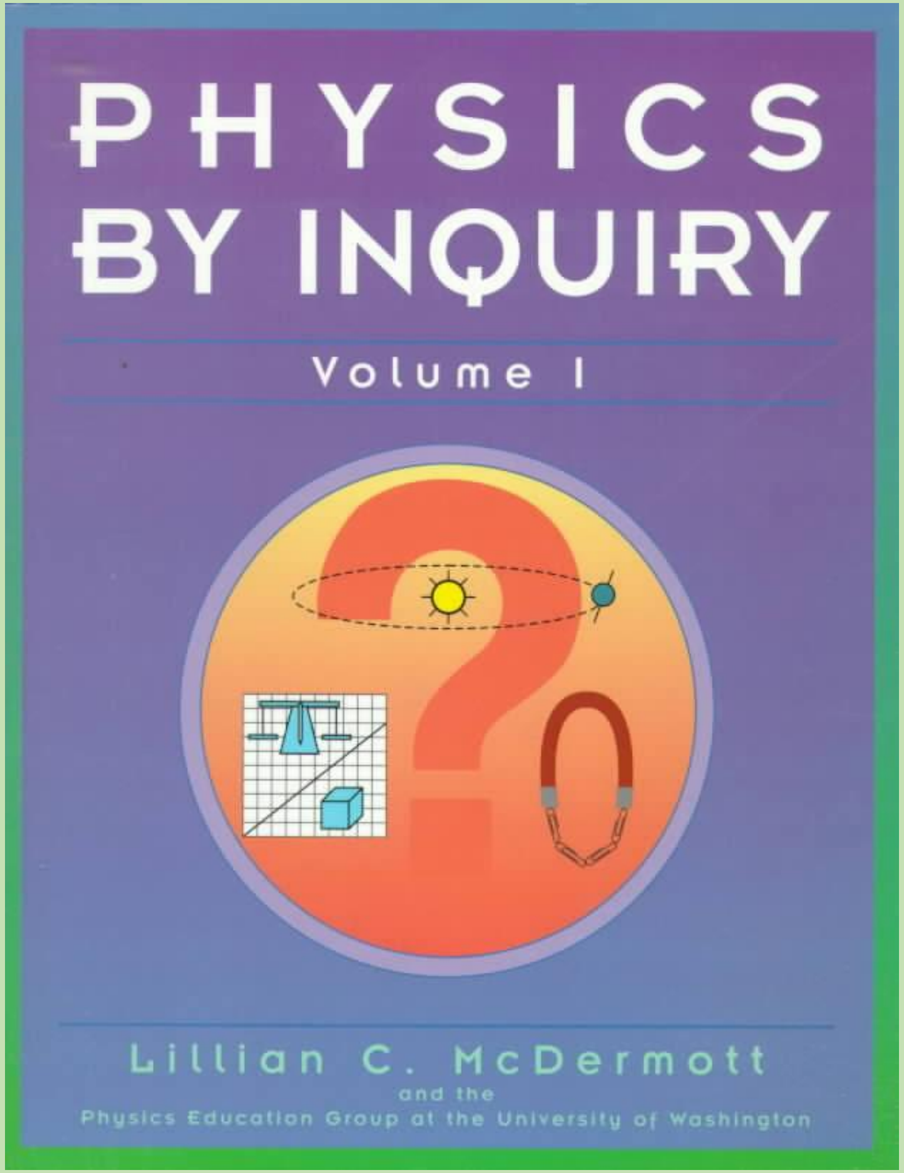
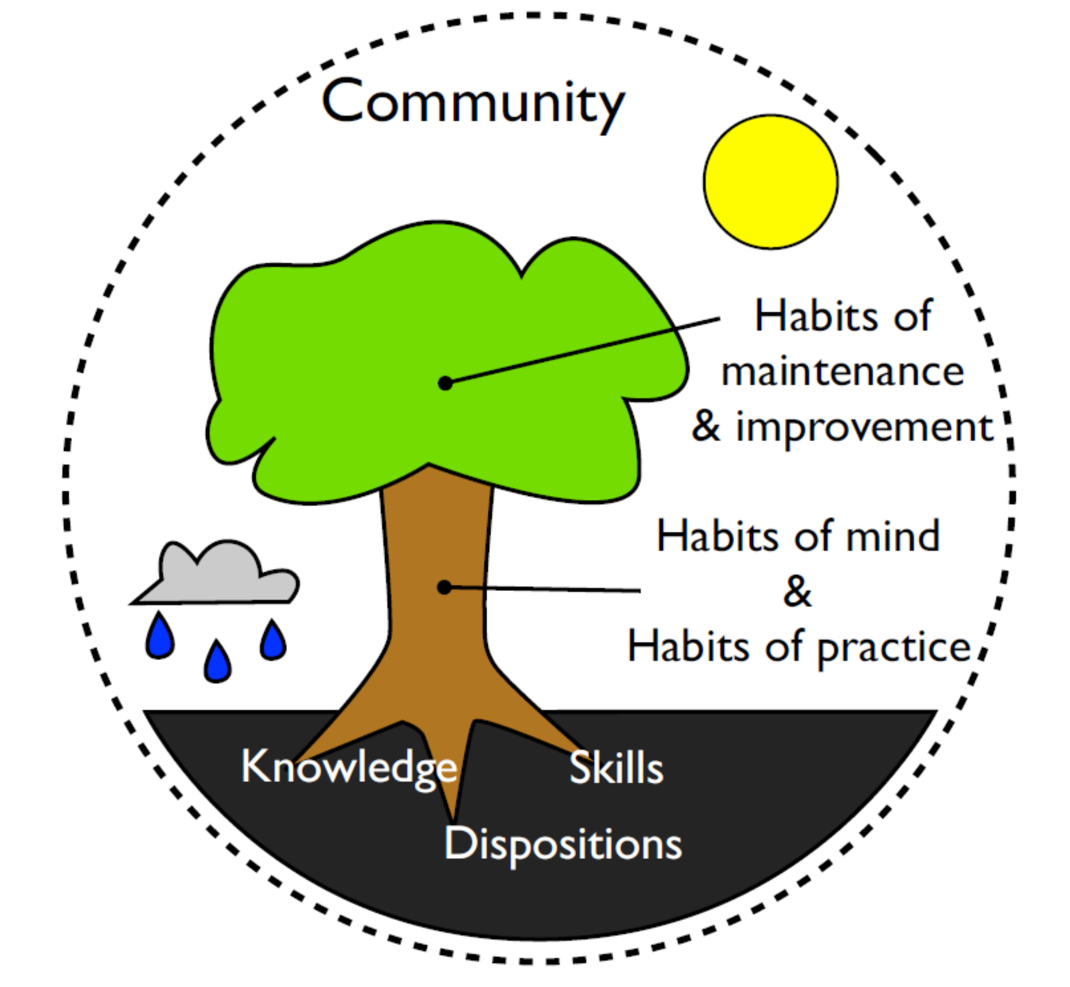

PHYSICS BY INQUIRY
Volume I
Lillian C. McDermott
and the
Physics Education Group at the University of Washington

PER Heroes III – Eugenia Etkina

PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH 13, 010107 (2017)

Organizing physics teacher professional education around productive habit development: A way to meet reform challenges

Eugenia Etkina,[1] Bor Gregorcic,[2,*] and Stamatis Vokos[3]



https://journals.aps.org/prper/abstract/10.1103/PhysRevPhysEducRes.13.010107

If only someone would write a short introduction to the best PER books and papers available, explaining why they are good and sharing some ‘highlights’?

Some Pillars of Physics Wisdom

(A physics education research primer)

Ideas from Physics Education Research to help you change your classroom

James de Winter

jad26@cam.ac.uk