Assessment and Instructional-Element Analysis in Evidence-based Physics Instruction

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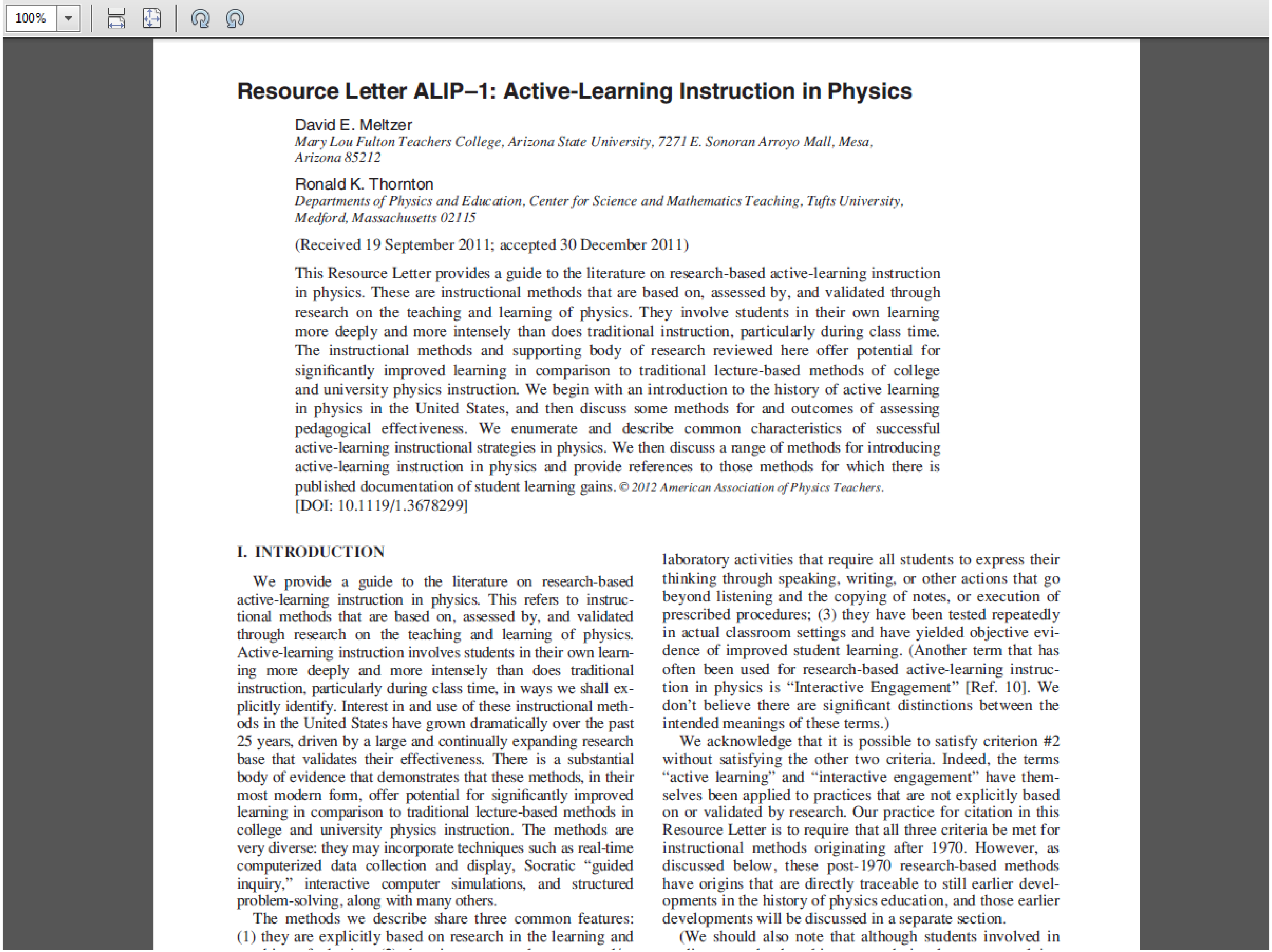
How Are Research-Based Physics Instructional Methods Assessed?

- Resource Letter ALIP-1 (Meltzer and Thornton, 2012): Compendium of ≈30 research-validated instructional methods/materials in physics
- Each method/material examined to determine which instruments and techniques were used to provide evidence of instructional effectiveness



Resource Letter ALIP–1: Active-Learning Instruction in Physics

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This Resource Letter provides a guide to the literature on research-based active-learning instruction in physics. These are instructional methods that are based on, assessed by, and validated through research on the teaching and learning of physics. They involve students in their own learning more deeply and more intensely than does traditional instruction, particularly during class time. The instructional methods and supporting body of research reviewed here offer potential for significantly improved learning in comparison to traditional lecture-based methods of college and university physics instruction. We begin with an introduction to the history of active learning in physics in the United States, and then discuss some methods for and outcomes of assessing pedagogical effectiveness. We enumerate and describe common characteristics of successful active-learning instructional strategies in physics. We then discuss a range of methods for introducing active-learning instruction in physics and provide references to those methods for which there is published documentation of student learning gains.
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I. INTRODUCTION

We provide a guide to the literature on research-based active-learning instruction in physics. This refers to instructional methods that are based on, assessed by, and validated through research on the teaching and learning of physics. Active-learning instruction involves students in their own learning more deeply and more intensely than does traditional instruction, particularly during class time, in ways we shall explicitly identify. Interest in and use of these instructional methods in the United States have grown dramatically over the past 25 years, driven by a large and continually expanding research base that validates their effectiveness. There is a substantial body of evidence that demonstrates that these methods, in their most modern form, offer potential for significantly improved learning in comparison to traditional lecture-based methods in college and university physics instruction. The methods are very diverse: they may incorporate techniques such as real-time computerized data collection and display, Socratic "guided inquiry," interactive computer simulations, and structured problem-solving, along with many others.

The methods we describe share three common features: (1) they are explicitly based on research in the learning and

laboratory activities that require all students to express their thinking through speaking, writing, or other actions that go beyond listening and the copying of notes, or execution of prescribed procedures; (3) they have been tested repeatedly in actual classroom settings and have yielded objective evidence of improved student learning. (Another term that has often been used for research-based active-learning instruction in physics is "Interactive Engagement" [Ref. 10]. We don't believe there are significant distinctions between the intended meanings of these terms.)

We acknowledge that it is possible to satisfy criterion #2 without satisfying the other two criteria. Indeed, the terms "active learning" and "interactive engagement" have themselves been applied to practices that are not explicitly based on or validated by research. Our practice for citation in this Resource Letter is to require that all three criteria be met for instructional methods originating after 1970. However, as discussed below, these post-1970 research-based methods have origins that are directly traceable to still earlier developments in the history of physics education, and those earlier developments will be discussed in a separate section.

(We should also note that although students involved in

Diagnostic “Instruments”

- **“Standardized” surveys:** ≈20-40 items, usually multiple-choice, qualitative (non-algebraic, non-numerical); Example: FCI
- **Researcher-constructed free-response questions:** qualitative emphasis; fewer than 8 items; may or may not require student explanations; Example: University of Washington assessment items
- **Instructor-constructed course assessments:** quizzes, exams, homework, grades; emphasis on quantitative and algebraic problem-solving

Comparison Groups

- **Local:** compare to similar courses at home institution that use standard instruction
- **External:** compare to similar courses/student populations at other institutions
- **National baseline:** compare to previously published data reflecting performance in representative equivalent courses at multiple institutions

Survey Instruments

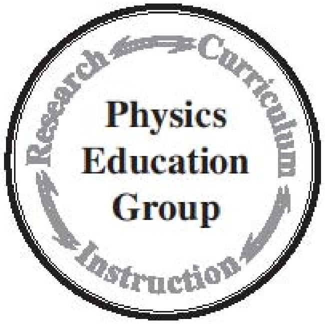
- **Frequently used:**
  - Force Concept Inventory (FCI)
  - Force and Motion Conceptual Evaluation (FMCE)
- **Occasionally used:**
  - Conceptual Survey in Electricity and Magnetism (CSEM)
  - Brief Electricity and Magnetism Assessment (BEMA)
- **Rarely used:**
  - Electric Circuits Concept Evaluation (ECCE)
  - Mechanics Baseline Test (MBT)
  - Colorado Upper-Division Electrostatics Diagnostic Quiz [non-MC] (CUE)
  - Quantum Mechanics Visualization Instrument (QMVI)
  - Quantum Mechanics Assessment Tool [non-MC] (QMAT)
  - Quantum Mechanics Conceptual Survey (QMCS)

Examples of Researcher-Constructed Free-Response Items

- University of Washington assessment items (published in AJP)
- University of Minnesota Context-Rich Problems (examples in AJP, others available in on-line compendium)

Pretest and post-test questions for assessment of student learning

Examples from research on Mechanics



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Other Outcomes Assessed

- Attitudes and beliefs (e.g., student ideas about how best to learn physics)
- Facility with physics practices (e.g., ability to design and execute experiment): rarely assessed
  - *Example:* Etkina and Van Heuvelen (2007)

Issues of Concern

- Most assessments done via multiple-choice survey instruments
  - (relatively) easy to implement
  - limited insight into student thinking: imprecise, and lack explanations
  - limited coverage of instructional intervention (narrow scope of topics)
- Most non-survey assessments unpublished
- Most comparison groups are limited in number and generalizability
- Most components of each collection of materials go unassessed
  - *Exception:* University of Washington; majority of UW Tutorials undergo extensive cycle of iterative assessment and validation

Assessment of Instructional “Elements”

- What is the relative impact of various instructional elements such as:
  - use/non-use of physical objects
  - size and composition of student groups
  - frequency and method of feedback provided
  - homework
  - TA preparation
  - classroom discussion format
- Rarely assessed due to logistical challenges
  - Notable exceptions: Koenig, Endorf, and Braun (2007); Morote and Pritchard (2009)

Summary Questions

- What assessment methods and materials yield optimum information regarding effectiveness of student learning?
- What assessment methods possess optimum potential to persuade skeptical instructors of the value of novel instructional methods?
- What are reasonable tradeoffs between constraints on time and resources vs. scope, validity, and reliability of assessments?