The Knowledge-Practice Gap in Physics Teaching: How Big Is it and Why Does it Exist?

Charles Henderson
Western Michigan University

homepages.wmich.edu/~chenders

AAPT Summer Meeting 2014, Minneapolis, MN
July 28, 2014, Talk CE01

Awards: #0715698, #1022186, #0623009, #0723699
Outline

• The Knowledge-Practice Gap
• The Knowledge-Practice Gap in Undergraduate Physics Education
• Theory: *Push-Pull Infrastructure Model* for Moving Research Findings into Practice
  – Applied to Undergraduate Physics Teaching
  – Applied to MOOCs
The Knowledge-Practice Gap

• Practitioners do not take up research-proven practices

• Problem is addressed by many research traditions
  – Knowledge Utilization
  – Diffusion of Innovations
  – Technology transfer
  – Marketing
  – Evidence-based medicine
  – Evidence-based public health
  – Organizational implementation

100,000 US Hospital Deaths Linked to Poor Hand Hygiene*

Hand Hygiene Prevents Patients from Catching Diseases.

http://info.debgroup.com/Portals/169265/images/4-2-2013%204-26%20pm-resized-600.jpg

*Daniel Pink, *Drive*
700,000 US Deaths Linked to Smoking and Obesity*

Knowledge-Practice Gap

• We have identified problems.
• We have identified solutions.
• The solutions are not implemented


Knowledge-Practice Gap in Undergraduate Physics Teaching

Context

• 661,000 Students take an introductory college-level physics course each year*
• 12,700 faculty (2- and 4-year colleges)*

*Data from AIP Statistical Research, http://www.aip.org/statistics
The Knowledge exists
Many Research-Based Instructional Strategies

some
Research-Based Instructional Strategies
for college-level introductory quantitative physics

UMN Online archive of context-rich problems: http://groups.physics.umn.edu/physed
Evidence of Effectiveness

“Novel curricula, materials, and approaches to instruction exist that have demonstrated improved results, not only in students’ conceptual and quantitative knowledge of physics, but also in their ability to engage in scientific inquiry.”
What is the knowledge-practice gap?

Web Survey (With Melissa Dancy)

– Administered by American Institute of Physics Statistical Research Center, Fall 2008

– Random sample:
  • 1) two year colleges
  • 2) four year colleges with a physics B.A.
  • 3) four year colleges with a physics graduate degree

– 722 useable responses (response rate 50.3%)

– Questions about knowledge and use of 24 Research-Based Instructional Strategies (RBIS)

What RBIS do faculty know about and use?

For All RBIS Surveyed
Knowledge:Practice ranged from 2.2 to 21.3, average = 7.7

<table>
<thead>
<tr>
<th>RBIS (Top 10)</th>
<th>Knowledge</th>
<th>Use</th>
<th>Knowledge : Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer Instruction</td>
<td>63.5</td>
<td>29.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Physlet</td>
<td>56.3</td>
<td>13.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Coop. Group Prob. Solving</td>
<td>49.3</td>
<td>13.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Workshop Physics</td>
<td>48.2</td>
<td>6.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Just-in-time Teaching</td>
<td>47.7</td>
<td>8.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Tutorials in Introductory Physics</td>
<td>47.0</td>
<td>7.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Interactive Lecture Demonstrations</td>
<td>45.4</td>
<td>13.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Activity Based Problem Tutorials</td>
<td>43.0</td>
<td>6.0</td>
<td>7.2</td>
</tr>
<tr>
<td>Ranking Tasks</td>
<td>38.7</td>
<td>15.4</td>
<td>2.5</td>
</tr>
<tr>
<td>SCALE-UP</td>
<td>34.5</td>
<td>3.3</td>
<td>10.4</td>
</tr>
</tbody>
</table>
Impact of Development and Dissemination on Undergraduate Physics Instruction

### From Web Survey – Use of ‘Essential Features’ of Peer Instruction

<table>
<thead>
<tr>
<th>Features of Peer Instruction (measured on survey)</th>
<th>Self-Described Users of Peer Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Lecture (for nearly every class or multiple times every class)</td>
<td>55%</td>
</tr>
<tr>
<td>Students discuss ideas in small groups (multiple times every class)</td>
<td>27%</td>
</tr>
<tr>
<td>Students solve/discuss qualitative/conceptual problem (multiple times every class)</td>
<td>27%</td>
</tr>
<tr>
<td>Whole class voting (multiple times every class)</td>
<td>38%</td>
</tr>
<tr>
<td>Conceptual questions (used on all tests)</td>
<td>64%</td>
</tr>
</tbody>
</table>

| Uses all 5 components                                                                                      | 6%                                      |
| Uses 4 or more of the 5 components                                                                         | 21%                                     |
| Uses 3 of more of the 5 components                                                                         | 35%                                     |

Use of ‘essential features’ was even lower for Cooperative Group Problem Solving.
26% (9/35) of faculty who say they are familiar with Peer Instruction only use the term in a literal way: 

*Peer Instruction* = any in-class or out-of-class activity where students worked with one-another.

Texas Tech: Drop in Peer Tutoring is available free to all currently enrolled students.
Conclusions (so far)

• Knowledge-practice gaps exist everywhere
• In undergraduate physics teaching:
  – Many research-based instructional strategies exist
  – The knowledge-use gap for individual strategies is high (average knowledge:use = 7.7)
  – Most faculty (88%) know about one or more
  – Most faculty (76%) have tried one or more
  – About half of faculty (49%) currently use one or more
  – The above self-report numbers are almost certainly higher than reality
Why Does the Knowledge-Practice Gap Exist?

Push-Pull Infrastructure Model: Moving Research Findings into Practice
Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

Push-Pull Infrastructure Model
Moving Research Findings into Practice

• In 1995 Robert Wood Johnson Foundation (RWJF) used this model to increase use of effective tobacco-cessation treatments
• The situation in 1995
  – Most smokers wanted to quit and more than half tried on their own. Only about 5% succeeded.
  – Evidence-based interventions were much more effective.
  – Few doctors asked about smoking or offered their patients proven help to quit.
• RWJF Invested $86M over 15 years
  – (NSF EHR budget is ~$850M annually)

Goal: Increase the use of effective tobacco-cessation treatments

**Push: Science Push**
Documenting, improving, and communicating the practice for wide use
- Develop and test novel interventions
- Communicate treatment recommendations to doctors and policy makers

**Infrastructure: Delivery Capacity**
Building the capacity of relevant systems to deliver the practice
- Implement systems to remind doctors to assist patients to quit and incentivize performance
- Develop training programs

**Pull: Market Demand**
Building demand for the practice
- Policy advocacy (tobacco taxes, smoke-free air laws, insurance coverage for treatment, etc.)
- Embed tobacco screening into quality care metrics
- Redesign treatment to be more appealing to smokers

Progress!

15 years into RWJF’s tobacco-cessation efforts:

• More former smokers than current smokers
• Adult smoking fell from 24.7% in 1995 to 20.5% in 2008
• Youth smoking fell from 33.5% in 1995 to 20% in 2007

Evidence-based interventions exist . . . . . but are not always used.
Push-Pull Infrastructure Model
Moving Research Findings into Practice

Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

Product
System
User
What does push look like?

• Primary emphasis of funding agencies and researchers

• Development and Dissemination:
  – New instructional strategies developed and tested by ‘experts’.
  – Strategies are then widely scattered (talks, workshops, publications) in the hopes that they will take root.
Widely Disseminated

From: http://mazur-www.harvard.edu/

Mazur has given over 600 talks about Peer Instruction (Mazur, April 2013, Personal communication).
Significant Materials Available

• 253 page book with detailed implementation recommendations and disk with ready-to-go materials:
  – In-class questions
  – Reading quizzes
  – Exam questions

• Publisher has distributed book for free to large numbers of US physics faculty.*
  – 18,700 copies shipped since 1996
  – 12,700 free

*From Mazur, 2009 AAPT Winter Meeting
How are we doing?

Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure:
Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

[Green check mark]
What would pull look like?

• Interactive development and dissemination: Develop products with user in mind
  – developers work with faculty from the beginning to understand challenges, needs, tacit knowledge from their teaching context
  – development with customization in mind
Developers do not Understand Users

• A common solution to lack of use is to collect more evidence of efficacy.
Developers do not Understand Users
Top Concerns that Faculty have about Peer Instruction

<table>
<thead>
<tr>
<th>Concern</th>
<th>% total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires time and energy to change</td>
<td>57.1</td>
</tr>
<tr>
<td>Content coverage concerns, personal belief</td>
<td>48.6</td>
</tr>
<tr>
<td>Difficulty to getting students engaged</td>
<td>48.6</td>
</tr>
<tr>
<td>Students aren’t capable of doing it</td>
<td>37.1</td>
</tr>
<tr>
<td>In personal experience it did NOT work</td>
<td>34.3</td>
</tr>
<tr>
<td>Structural, lack of resources</td>
<td>34.3</td>
</tr>
<tr>
<td>Structural, class size</td>
<td>31.4</td>
</tr>
<tr>
<td>Structural, lack of appropriate classroom</td>
<td>31.4</td>
</tr>
<tr>
<td>Trouble finding good questions</td>
<td>31.4</td>
</tr>
<tr>
<td>Difficulty getting student buy-in</td>
<td>28.6</td>
</tr>
<tr>
<td>Current practices are effective</td>
<td>25.7</td>
</tr>
<tr>
<td>Intuitively don’t think that PI will work</td>
<td>25.7</td>
</tr>
<tr>
<td>Content coverage concerns, external requirements</td>
<td>22.9</td>
</tr>
<tr>
<td>Content coverage concerns, institutional expectations</td>
<td>20.0</td>
</tr>
</tbody>
</table>
What would pull look like?

- Interactive development and dissemination: Develop products with user in mind
  - developers work with faculty from the beginning to understand challenges, needs, tacit knowledge from their teaching context
  - Development with customization in mind
- Build momentum
  - Work to change attitudes about evidence-based teaching
  - Change culture so that failure to use evidence-based practices is considered inappropriate
How are we doing?

Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

[Green check mark] [Red X]
What would infrastructure for delivery look like?

- Develop mechanisms for coordinating information about evidence-based teaching
- Develop structures to support individuals interested in changing their instruction (especially at first)
- Develop institutional structures and systems that encourage use of evidence-based practices
- Develop extra-institutional policies that support use
How are we doing?

Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice
Conclusions (so far)

For evidence-based instructional strategies:

• **Push**
  - Strategies exist, Evidence is strong, Widely available

• **Pull**
  - Work on individual level to build demand has been somewhat successful
  - Little interactive development and dissemination

• **Infrastructure**
  - Promising delivery mechanisms in early stage
  - Structural barriers to use remain strong
  - Lack of support results in high discontinuation
MOOCs rising

Over little more than a year, Coursera in Mountain View, California — the largest of three companies developing and hosting massive open online courses (MOOCs) — has introduced 328 different courses from 62 universities in 17 countries (left). The platform’s 2.9 million registered users come from more than 220 countries (centre). And courses span subjects as diverse as pre-calculus, equine nutrition and introductory jazz improvisation (right).

### Supply and demand

<table>
<thead>
<tr>
<th>Number of courses available on the platform</th>
<th>Number of user accounts on the platform (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>350</td>
<td>0.5</td>
</tr>
<tr>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td>250</td>
<td>1.5</td>
</tr>
<tr>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
</tr>
<tr>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>50</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**February 2012**

**March 2013**

### Student origins

- 27.7% United States
- 8.8% India
- 5.1% Brazil
- 4.4% United Kingdom
- 4% Spain
- 3.6% Canada
- 2.3% Australia
- 2.2% Russia
- 41.9% Rest of world

### Courses offered

- 6% Mathematics
- 30% Science
- 13% Business
- 28% Arts and humanities
- 23% Information technology
Applying the Model
(from the perspective of a MOOC supporter)

Goal: Increase the use of MOOCs

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice
Push: Science Push
Documenting, improving, and communicating the practice for wide use

<table>
<thead>
<tr>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lots of communication about benefits (e.g., low cost)</td>
<td>Also communication about problems, (e.g., credit for completion)</td>
</tr>
<tr>
<td>Work being done to document effectiveness</td>
<td>Evidence is so far inconclusive. Many concerns about quality and completion rates exist.</td>
</tr>
<tr>
<td>Methods for automated personalized online instruction continue to improve and show promise.</td>
<td>No clear “best practices” exist to guide implementation</td>
</tr>
<tr>
<td></td>
<td>But, still lag behind high quality traditional or blended learning environments.</td>
</tr>
</tbody>
</table>
Applying the Model (from the perspective of a MOOC supporter)

Goal: Increase the use of MOOCs

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

Need more research
- What practices improve student learning?
- What are affordances & constraints of MOOCs
Pull: Market Demand
Building demand for the practice

Beyond the MOOC Hype
What new tech trends will knock massive open online courses out of the spotlight this year?

If as the New York Times declared, 2012 was "the Year of the MOOC," then 2013 might well be called "The Year of MOOC hype."

It's always a little sad to see an ed-tech innovation with so much potential fail prey to the backlash spawned by overexposure. Though the past year has seen plenty of interesting experimentation with MOOCs — particularly blended models — I can recall more than one presenter at the Campus Technology and Educause annual conferences last year actually apologizing for adding, yet again, the dreaded "M" word to the conversation.

Even legitimate concerns from faculty and academic technologists about the efficacy of rate training, he managed to recapture our attention in one fell swoop. How can one avoid open online college courses? And where do MOOCs go from here? The truth is, the underlying education are ongoing. As media told CT in our coverage, now we'll be talking about MOOCs in 2014, not much attention to getting faculty interested in developing a MOOC.

Involving “thought leaders”, Harvard, MIT, etc.
Attempts to position MOOCs as a “disruptive innovation”

<table>
<thead>
<tr>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Much excitement</td>
<td>Excitement may be waning</td>
</tr>
<tr>
<td>Easy for students to enter</td>
<td>Easy for students to drop out</td>
</tr>
<tr>
<td>Not much attention to getting faculty interested in developing a MOOC</td>
<td>Not much attention to getting “regular” institutions into the MOOC game</td>
</tr>
</tbody>
</table>

http://mfeldstein.com/emerging_student_patterns_in_moocs_graphical_view/
Applying the Model (from the perspective of a MOOC supporter)

Goal: Increase the use of MOOCs

**Push: Science Push**
Documenting, improving, and communicating the practice for wide use

**Infrastructure: Delivery Capacity**
Building the capacity of relevant systems to deliver the practice

**Pull: Market Demand**
Building demand for the practice

Need more research:
- What practices improve student learning?
- What are affordances & constraints of MOOCs

Need to build demand:
- What are students looking for?
- Why would an instructor teach a MOOC? What support do they need?
- How can MOOCs work with existing institutions?
Infrastructure

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

<table>
<thead>
<tr>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical aspects of delivery are being worked out</td>
<td>Assessment and credit are unsolved problems</td>
</tr>
<tr>
<td>Businesses being formed</td>
<td>Cost structure (business model) is an unsolved problem</td>
</tr>
</tbody>
</table>
Applying the Model
(from the perspective of a MOOC supporter)

Goal: Increase the use of MOOCs

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Need more research
• What practices improve student learning?
• What are affordances & constraints of MOOCs

Infrastructure: Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Need to develop systems to support MOOCs
• Business model
• Credentialing
• Authentication

Pull: Market Demand
Building demand for the practice

Need to build demand:
• What are students looking for?
• Why would an instructor teach a MOOC? What support do they need?
• How can MOOCs work with existing institutions?
Summary: Applying the Model
(from the perspective of a MOOC supporter)

Goal: Increase the use of MOOCs

**Push: Science Push**
Documenting, improving, and communicating the practice for wide use

**Infrastructure:**
Delivery Capacity
Building the capacity of relevant systems to deliver the practice

**Pull: Market Demand**
Building demand for the practice

Need to improve the product
Need to make product compatible with system (or change system)
Need to learn from users (and potential users)
Evidence-based interventions exist . . . . . but are not always used.
Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure:
Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

Product
System
User
Take Away Message

Goal: Increase the impact of evidence-based practice

Push: Science Push
Documenting, improving, and communicating the practice for wide use

Infrastructure:
Delivery Capacity
Building the capacity of relevant systems to deliver the practice

Pull: Market Demand
Building demand for the practice

Product
System
User