Intervention to Prevent Degradation of Students' Epistemologies

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November 5, 2016

The Hidden Curriculum

Physics Content

- Kinematics
- Newton's laws
- Conservation of energy
- Conservation of momentum
- Rotation
- Etc

Hidden Curriculum

- Problem solving
- Scientific thinking skills
- Nature of science
- How to learn
- Affective domain
- Etc

Epistemology – Beliefs about the nature of science and learning

Typical Epistemology Changes

CLASS instrument from U of Colorado

Category	Pre	Standard deviation	Post	Standard deviation
Overall	65(1)%	16	59(1)%	20
Real world connections	72(1)%	28	65(2)%	32
Personal interest	67(1)%	28	56(2)%	32
Sense making/effort	73(1)%	22	63(1)%	27
Conceptual connections	63(1)%	25	55(1)%	28
Applied conceptual understanding	53(1)%	25	47(1)%	28
Problem solving general	71(1)%	23	58(1)%	28
Problem solving confidence	73(1)%	27	58(2)%	33
Problem solving sophistication	61(1)%	29	46(2)%	32

Significant losses are normal

Adams et al., Physical Review Special Topics – PER, **2**, 010101 (2006)

Why Epistemology Matters

<u>More expert-like epistemology is correlated with:</u>

- Choosing physics major
  Lock et al., PERC 2015 proceedings, 100-202
- Persistence in major
  Gire et al., PRST-PER, **5**, 010103 (2009)
- Metacognition and better learning strategies
  May and Etkina, Am. J. Phys., **70** (12), 1249-1258 (2002)
- Conceptual learning gains
  Adams et al., PERC 2004 proceedings, 61-64

APU Physics FI Overview

- Four themes:
  1. Characteristics of scientists
  2. Nature of science
  3. Role of science and technology in society
  4. Theological implications of science

- Themes introduced in intro courses
- Topics in depth in each theme in upper-level courses

Example class discussion topic

Topic #13:

"Something to remember about mathematics is the importance of failure. If most of your attempts are successful, then you're not attempting anything really interesting. On the other hand, if 90% of your attempts are failing, then you are probably doing some interesting mathematics. So please remember, experiment, have fun, and don't worry about failing. Failing will only teach you more math."

Paul Zeitz
University of San Francisco

Do you agree or disagree with this quote? Why is it important that a scientist or mathematician be willing to risk trying something that they aren't sure will work? What role does trying something that ultimately doesn't work play in learning?

Survey instrument details

Epistemological Beliefs Assessment in the Physical Sciences

Axis	Novice view	Expert view
1 – Structure of scientific knowledge	Collection of unconnected facts	Hierarchical and coherent
2 – Nature of knowing and learning	Memorizing over sense-making	Actively checking and integrating
3 – Real-world applicability	Compartmentalized to classroom	Applied to the real world
4 – Evolving knowledge	Rigid or relative	Evolves with evidence
5 – Source of ability	Fixed and innate	Growth mindset

Research design

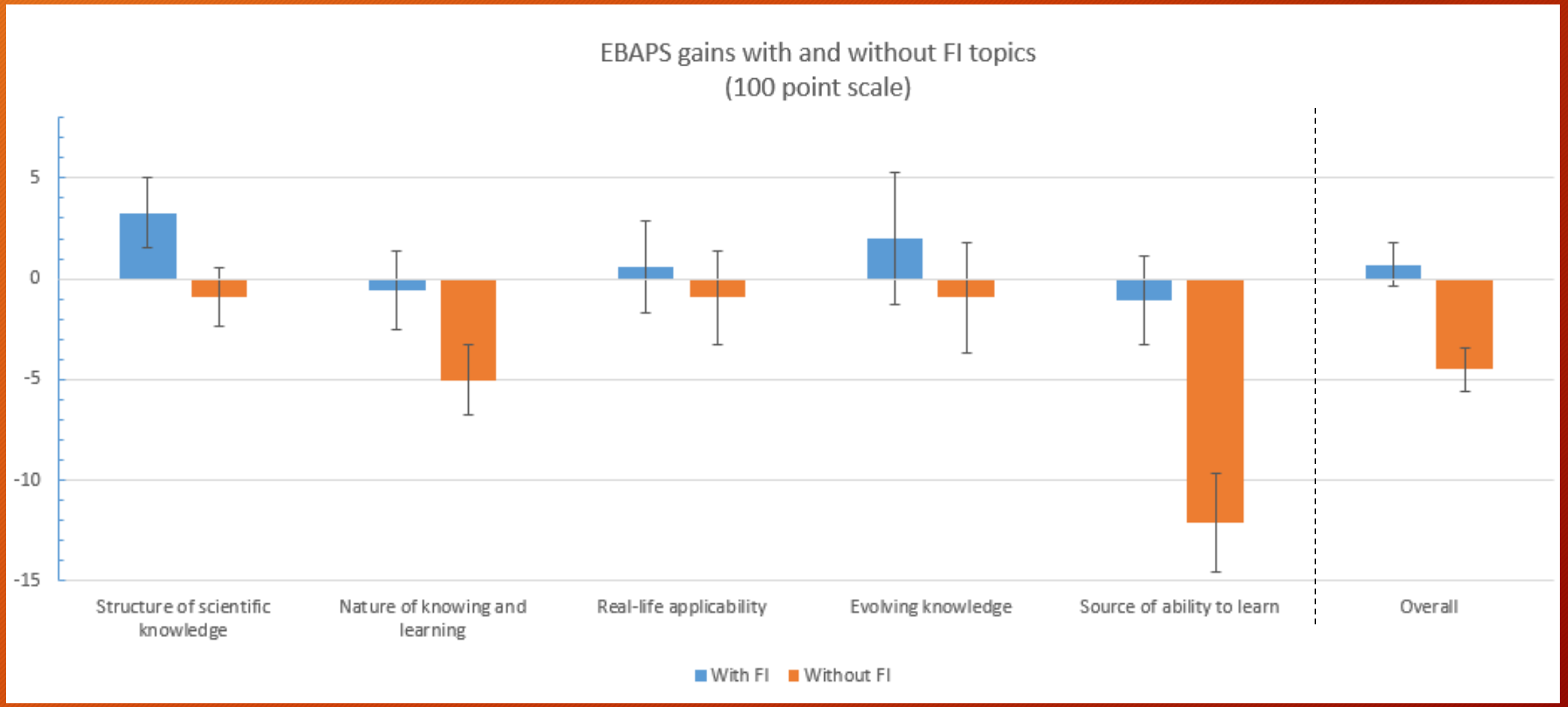
- Epistemological Beliefs Assessment in the Physical Sciences (EBAPS) survey
- Administered pre and post

- 3 sections of Physics for Science & Engineering I without FI topics (N=64)
- 2 sections with FI topics (N=66)

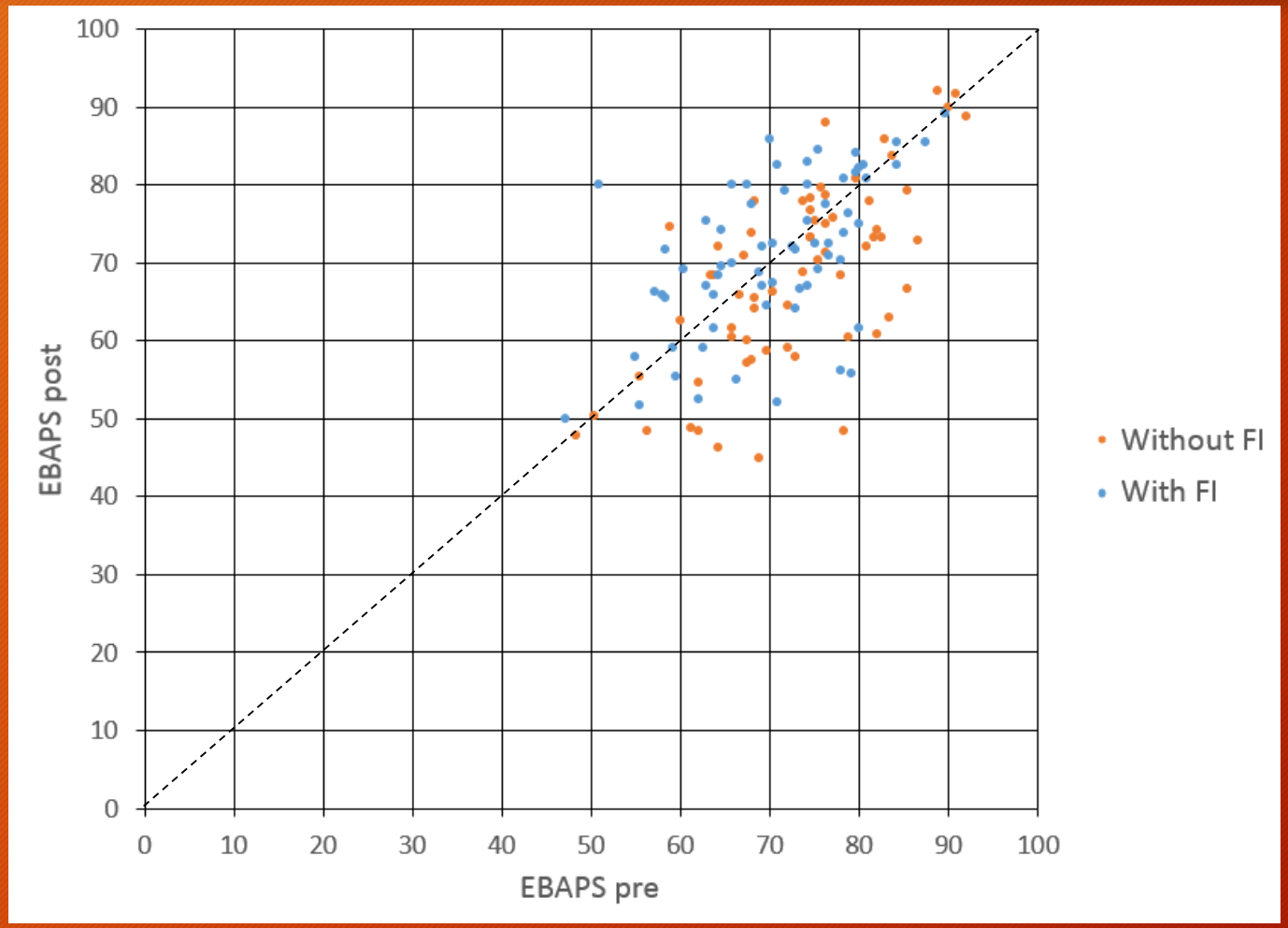
Limitations:

- Different instructors
- Not controlled for other pedagogies

Results


EBAPS gains with and without FI topics
(100 point scale)
5
0
-5
-10
-15
Structure of scientific knowledge
Nature of knowing and learning
Real-life applicability
Evolving knowledge
Source of ability to learn
Overall
With FI
Without FI

Individual student results



FI reduced # of students with large losses

Conclusions

- Epistemological gains help with recruiting, retention, and learning
- Discussion of epistemological topics improves students' understanding of science
- Substantial epistemological gains are possible with short in-class discussions

Statistics

	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Overall
Gain w/ FI	3.276515	-0.56818	0.568182	2.020202	-1.06061	0.713384
SE	1.75386	1.961868	2.280091	3.258983	2.208574	1.095575
Gain wo/ FI	-0.92014	-5.0293	-0.92773	-0.91146	-12.1094	-4.49309
SE	1.472715	1.752627	2.342385	2.747336	2.467056	1.100027
Difference in gain	**4.196654**	**4.461115**	**1.495916**	**2.93166**	**11.04877**	**5.206469**
p	0.07	0.093	0.648	0.494	0.001	0.001
Cohen's d	2.591487	2.398201	0.647174	0.972669	4.719084	4.742624
Pearson r	0.791656	0.767985	0.30787	0.437355	0.920725	0.921419

EBAPS sample questions

Axis	Sample question
1 – Structure of scientific knowledge	Scientists should spend almost all their time gathering information. Worrying about theories can't really help us understand anything.
2 – Nature of knowing and learning	When learning science, people can understand the material better if they relate it to their own ideas.
3 – Real-world applicability	Understanding science is really important for people who design rockets, but not important for politicians.
4 – Evolving knowledge	**Jose:** In my opinion, science is a little like fashion; something that's "in" one year can be "out" the next. Scientists regularly change their theories back and forth. **Miguel:** I have a different opinion. Once experiments have been done and a theory has been made to explain those experiments, the matter is pretty much settled. There's little room for argument.
5 – Source of ability	Given enough time, almost everybody could learn to think more scientifically, if they really wanted to.

APU Physics FI curricular map

Course	Theme	Topic
Physics for Science & Engineering I	Characteristics of scientists	Overview
Physics for Science & Engineering II	Nature of science	Overview
Physics for Science & Engineering III	Science in society/Theological implications	Overview
Electricity & Magnetism	Nature of science	Scientific worldview
Waves & Optics	Nature of science	What is “truth”
Classical Mechanics	Characteristics of scientists	Doubt and skepticism/Galileo affair
Thermodynamics	Theological implications	Big Bang
Mathematical Methods for Phys/Engr	Science in society	Science as vocation
Quantum Mechanics	Science in society	Scientists in public policy
Advanced Lab	Characteristics of scientists	Research ethics
Physics Seminar	Characteristics of scientists	Personal values

Example class discussion topic

Topic #18:

Often when scientists are portrayed in movies or other popular culture, they are characterized as being arrogant. Why might scientists appear this way to the general public? Is arrogance in fact a common trait of scientists? If so, what makes scientists prone to this bad trait and what steps can we take to avoid arrogance?

Definitions

- Faith Integration - Reflection/discourse on the relationship between theology, faith practice, and academic disciplines

- Epistemology – Beliefs about the nature of science and learning

Premise: Epistemology is an important component to faith integration in science disciplines.