Improving the Epistemological Beliefs of Non-STEM Majors Towards Science

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Discussion

What makes a "good" student?

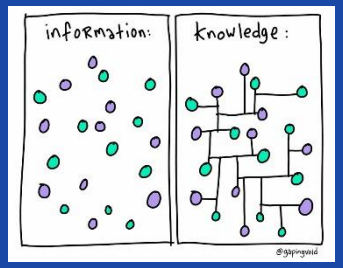
What prevents a student from being a "good" student?

What are Epistemologies?

- "Beliefs or views about how knowledge is constructed and evaluated."[1]
- "Beliefs about the nature of knowledge and learning." [2]
- A "Set of views about the nature of knowledge, knowing, and learning." [3]

Aspects of Epistemology [4,5]

- Certainty of Knowledge (Fixed vs. Dynamic)
- Simplicity of Knowledge (Isolated vs. Interconnected)
- Source of Knowledge (Authority vs. Self)
- Justification of Knowing (Inherited vs. Constructed)



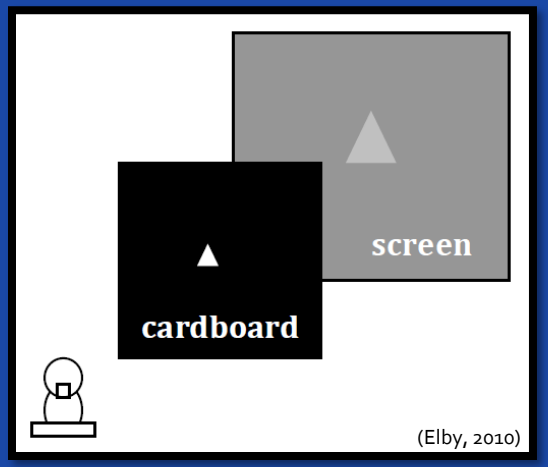
- Real World Applicability (Does science apply outside the classroom?)
- Ability (Innate vs. Effort)
- Quick Learning
- Formula vs. Concept

Discussion

How do you think your views differ from those of your students?

Example From Literature[6]

Light and Shadows Tutorial in Introductory Physics:



- In tutorial, students are to experiment with light and predict various patterns that will be seen on a screen.
- Jan struggles to comprehend the path taken by the light on its way to the screen.
- Jan keeps attempting to fit what she is seeing with "physics-oriented" language (vector, polarized, etc.).
- "Jan behaves as if common sense reasoning is a separate endeavor from formal (mathematical or technical) reasoning"
- Epistemic shortcoming: Jan doesn't seek connections between formal and informal reasoning

Might my students be struggling with an epistemic issue?

Ask yourself:

- Is my student "failing to use skills or knowledge they clearly possess?"[6]
  - Jan wasn't utilizing informal reasoning despite being capable of:
    - Discussing physics using informal reasoning
    - Checking her understanding
    - Working through physics problems in which she has little formal knowledge
- Is my student very hard-working, yet consistently performs poorly on examinations or inquisitions regarding their knowledge?

Discussion

Have you noticed any struggles and/or triumphs within a classroom that may relate to aspects of epistemology?

The Problem at Hand

Across the nation student epistemologies in science have been seen to deteriorate after a semester of traditional instruction.

Examples in Literature:

How College-Level Introductory Instruction Can Impact Student Epistemological Beliefs.[4]

Attitudes of Undergraduate General Science Students Toward Learning Science and the Nature of Science.[7]

Peer Instruction in introductory physics: A method to bring about positive changes in students' attitudes and beliefs.[8]

Student expectations in introductory physics[9]

Attitudinal gains across multiple universities using the Physics and Everyday Thinking curriculum.[13]

What Have We Done?: Course revisions

- Material added to shorter lectures
- Some content was reduced
  - Less about telescopes
  - Magnitude scale eliminated
  - Solar system section
- More in class writing
- More out of class time spent considering the applicability of science

What Have We Done?: Metacognitive tasks

- Muddiest point
  - "What part of today's lecture did you find most confusing?"
- Exam reflection
  - "How did you study for the exam?"
  - "Did you feel prepared?"
  - "Study and classify the types of errors you made."
- Write your own exam question

What Have We Done?: Science versus pseudoscience

- Astrology points to ponder

C. Positions A and B have equal pull on my body
D. I don't know

- Why doesn't the moment of conception matter?
- Your sign isn't what you think it is!

What Have We Done?: Science in the media

- Guided practice in discerning science in news sources
  - Is it reliable?
  - Are personal beliefs driving the claim?
  - Do you agree with the conclusions drawn by the author?
  - Do other sources agree with this source?
  - Where does the preponderance of evidence point?

Apollo moon landing hoax

Apollo Moon Conversations and Pictures Show NASA Cover-up

You may have read my Apollo hoax article elsewhere on this web site, where I believe that the Apollo footage that has been released by NASA seems to be a hoax. I have uncovered various pictures and transcripts of astronaut conversations from the Apollo missions that relate to encounters with UFOs, and perhaps this is one reason why NASA would release fake footage to the general public. The following are excerpts of conversations from Apollo Astronauts on the Moon to Mission Control - which show that the Astronauts came across some strange and hard-to-explain structures and unusual sightings of unidentified craft - whilst on the surface of the Moon.

In the photo to the right, you can see an Apollo astronaut stepping down onto the Moon. In the background, space, the final frontier. Or is it a Hollywood backdrop, the ultimate deception? Many people feel we have not been told the complete truth regarding NASA's space program, in particular the Apollo Missions of the late 60's and early 70's. Recent research has shown that conditions on the Moon could be very different from the 'official-line' which NASA would lead us to believe. Dr Farouk El Baz, one of NASA's foremost scientists, confirmed public suspicions when he stated *'not every discovery has been announced to the public'*. Is this the understatement of the millennium?Why is it that relatively few people have been allowed total access to the massive NASA archives (photographs which are supposedly in the public domain). Instead we have to make do with the two or three dozen 'reproductions' that appear in the 'official' textbooks, despite literally millions of photographic images obtained by NASA. Something is seriously amiss. Also the original photographs are huge (32"x24") so by the time they have been reduced to fit the pages of a regular book the clarity and quality reduced by the copying process make most of the images pretty meaningless. In many cases, researchers are left with little more than 'smudges' and 'blurs'.

Even so, despite all these obstacles, there is still hard evidence when these photographs are scrutinized under the proverbial - and literal - microscope, that points to the fact that virtually everything NASA has told us about the moon is a lie.

The REAL NASA MOON PHOTOS, for example show all kinds of structures, seemingly both old and new, such as domes, pipelines, and even pyramids. So why aren't these photos in the public domain? You can see in several of NASA's film footage, the American flag 'flapping in the wind' and yet the Moon according to NASA has no atmosphere, because it is a vacuum! One film clearly shows a desperate astronaut trying his level best to hold the flag still!

We are also told that the famous Neil Armstrong 'footprints' will remain etched on the Moon's surface forever. We are told this precisely because the Moon's 'atmosphere' is a vacuum. The laws of physics demand that dust becomes hardened and will compress in a 'vacuum' therefore ensuring the *'footprints'* remain undisturbed. And yet great plumes of dust can be seen spewing forth from underneath the 'Moon Buggy' as it travels across the lunar surface. Is this 'vacuum theory' some kind of wild hoax by NASA?

Another NASA cover-up are the small cloud formations that have been photographed above the Moon, again in a vacuum?. And while were on the subject of clouds what about the ONE HUNDRED MILE WIDE CLOUD OF VAPOR that was detected by NASA's own instruments. This embarrassing *'anomaly'* was promptly dismissed by NASA scientists as being the result of the considerable volume of urine ejected by the Apollo Mission astronauts! What were they drinking?!

For decades strange 'lights' and artificial seeming structures have been observed and recorded on the Moon by amateur astronomers. Science writer Joseph Goodavage observed that over two hundred white *'dome shaped'* structures had been seen and catalogued, only for them often to vanish and reappear somewhere else?. There are even colour photos from the Apollo 8 missions that clearly show evidence of green vegetation on the lunar hills.

These unusual findings, when added together with the anomalies which Richard Hoagland has shown to exist on Apollo Moon photographs, provide compelling evidence for an ongoing NASA cover-up of what the Apollo Astronauts really discovered on the Moon from 1969 to 1972.

The following Apollo Astronaut conversations were mostly taken from the out-of-print book "Our Mysterious Spaceship Moon" by Don Wilson (Dell, 1975):

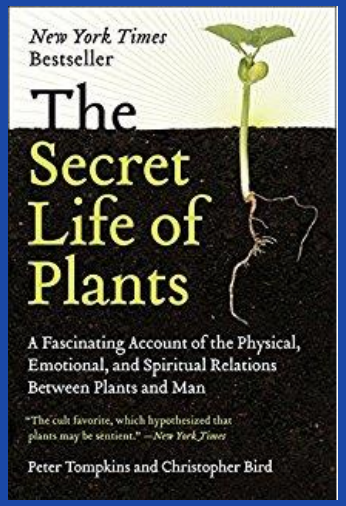
Apollo 16 Mission: April 16 - 27, 1972

Charles Duke, Thomas Mattingly and John Young land in the Descartes highlands:

Duke: These devices are unbelievable. I'm not taking a gnomon up there.

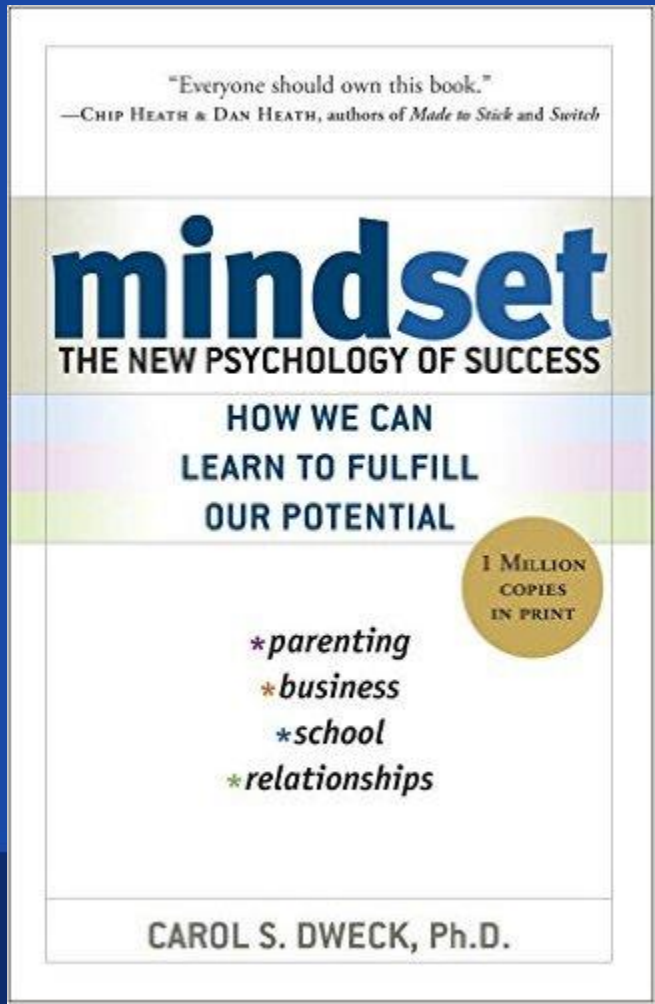
What Have We Done?: Science in the media

- New desalinization techniques
- China's giant telescope
- Life has gotten louder
- Birth control has negative side effects
- South Africa's solar powered airport
- World's smallest working transistor
- How did Lucy die?



What Have We Done?: Encouraging a growth mindset

- Students discuss what they are good at, how they got good at it
- We ask students to participate in their learning
- Clicker questions encourage critical thinking and group discussion
  - Not graded on correctness



Results/Findings

Why science teachers should not be given playground duty.

Before Course Revisions

- Significant Overall deterioration of epistemologies in baseline
  - Innate vs. Effort, Fixed vs. Dynamic, and Authority vs. Self

After Course Revisions

- No overall significant deterioration
  - No longer significant deterioration along Certainty of Knowledge
  - Significant improvement along Simplicity of Knowledge
  - Significant deterioration along Nature of Knowing persists
  - Significant deterioration along Innate vs. Effort persists

Discussion

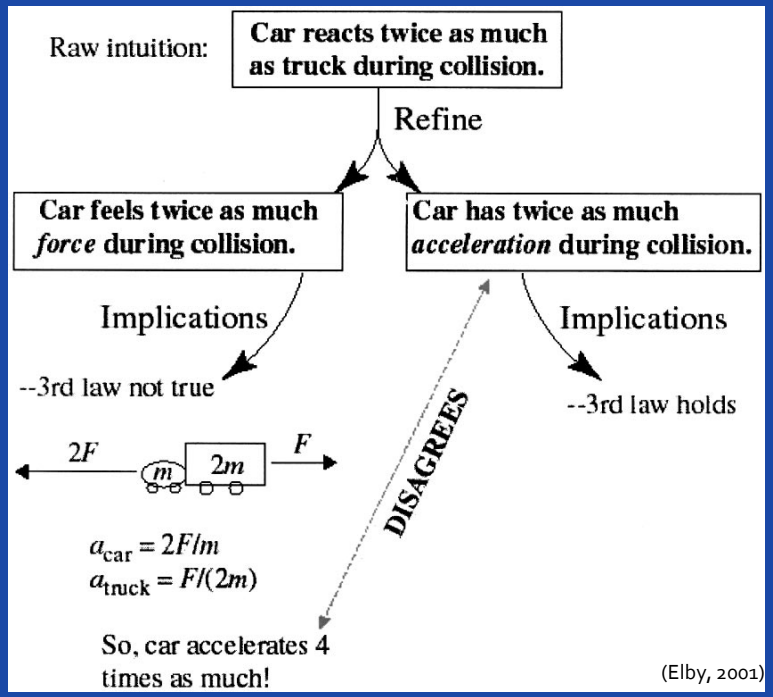
What courses do you instruct?

What struggles might you encounter when trying to improve student epistemologies?

Improvements in Epistemologies

Explicitly Embedding Epistemology Lessons into the Course[12]

- Emphasis on refining intuitive ideas and that physics is more conceptual than factual
- Homework graded on effort (thoughtfulness)
- Detailed solutions for some assigned questions were handed out
- Mini-quizzes were given each week to test conceptual understanding
  - No plug-and-chug questions
- Small group work with problems and activities similar to *Tutorials in Introductory Physics*[17]



Improvements in Epistemologies

Physics and Everyday Thinking / Physical Science and Everyday Thinking

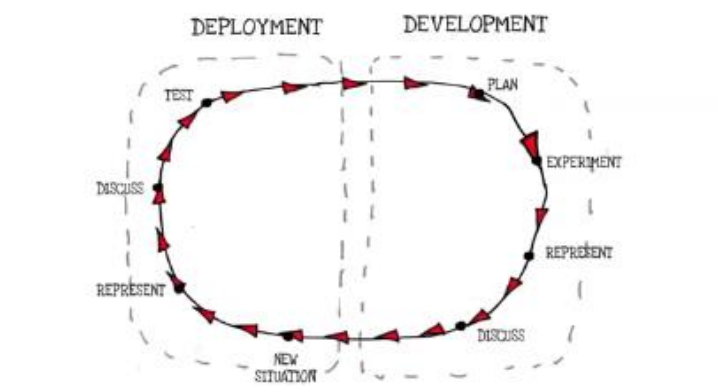
- PET Single Semester curriculum
  - Physics Content
    - Guided experimentation
    - Inquiry
    - Small group work
    - Class discussions
  - Nature of Science
    - Pillars of science and scientists
  - Learning about learning
    - Opportunity to understand their own learning process
    - Opportunity to expose the aspect of creativity and imagination within science

PET/PSET use across several institutions and/or instructors[13]

Improvements in Epistemologies

Modeling Instruction Curriculum[18]

- Frequent use of model development to test and predict phenomena
  - Instructor puts forth a question and/or demo that exemplifies an occurrence in nature
  - Students collaborate together in small groups to develop and validate ideas
  - Instructor provides Socratic dialog in guiding students



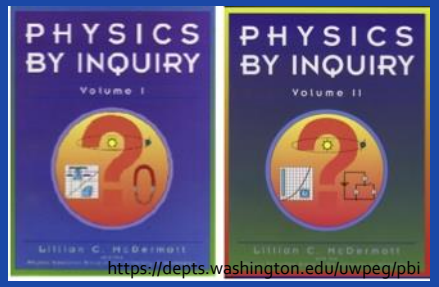
https://modelinginstruction.org/sample-page/synopsis-of-modeling-instruction/

Results Across One and Two Semesters of an Introductory Physics Course[14]

Improvements in Epistemologies

Physics By Inquiry (PBI)

- Students work together in small groups
- Limited to no lecture time
- Experiment guided by worksheets/tutorials
  - Test, Develop, Modify
- Instructor/TAs serve a Socratic role



https://depts.washington.edu/uwpeg/pbi

PBI Across several Institutions and Implementations[15]

Discussion/Hands-On

What patterns do you see in these curricula?

Modeling

Frequent use of model development to test and predict phenomena

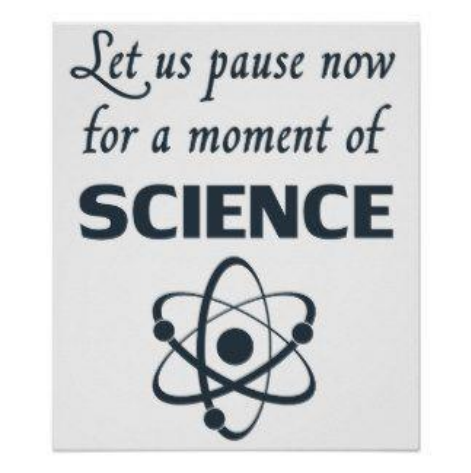
- A question, observation, or demo that exemplifies an occurrence in nature is put forth
- Experiment guided by worksheets/tutorials
  - Observe, Develop, Test, Modify, Collaborate
- Students collaborate together in small groups to develop and validate ideas
- Limited to no lecture time
- Instructor/TAs serve a Socratic role

Implicit and/or explicit utilization of Nature of Science principles

Nature of Science

Prominent Elements of the Nature of Science[10]

- Scientific knowledge is tentative
- Science relies on empirical evidence
- Science relies on skepticism
- Science is an attempt to explain phenomena
- All cultures can contribute to science
- New knowledge must be reported clearly and openly
- Scientists require replicability and truthful reporting
- Scientists are creative
- Change in science occurs gradually
- Science has global implications
- Science is part of social and cultural tradition
- Science has played an important role in technology
- Scientific ideas are affected by their social and historical milieu
- Nature of Science in the classroom



Epistemological Focus

Explicit focus on aspects of epistemology

- Student as sense-maker
- Testing limitation/applicability of knowledge
- Evaluation of knowledge
- Conceptual knowledge as important

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Troubleshooting

I need help with...

- covering enough material
- supporting group work
- arguments for skeptical colleagues

Where can I find good activities for small group discussions?

by Sam McKagan, PhysPort director — September 26, 2016

Nearly all research-based teaching methods in physics involve some kind of small group discussions of challenging conceptual activities. Finding good activities is an important component of making small group discussions work in your class. This recommendation includes links to collections where you can find activities to use in your class.

active learning, SCALE-UP, Peer Instruction, CAE Think-Pair-Share, Technology-Enhanced Formative Assessment, clickers, cooperative groups **Read more »**

What racial, gender, and sexual orientation bias still exists in physics and what can I do about it?

by Ramón S. Barthelemy — February 10, 2016

As physicists we often believe that our field is a place where anyone can succeed regardless of race, gender, or sexual orientation. Although overt discrimination has decreased, many kinds of unintentional and intentional bias still run rampant. Fortunately, many of these biases are identifiable and there are actionable steps your department can take to prevent and address…

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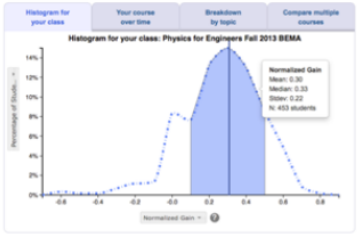

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Mountains & Minds

Meta-Analysis

Analysis of 24 studies involving use of MPEX and CLASS in undergraduate physics[11]

- Modeling (9.3%) and Explicit Focus (8.5%) courses are not significantly different in their effect on epistemic beliefs
  - Modeling is significantly better than courses which have some focus on epistemic beliefs (.7%) and ordinary methods (-3.7%)
  - Explicit is significantly better than courses employing ordinary methods
- Student population on shifts in epistemologies
  - Elementary Education & non-science majors experienced significantly greater gains than those in Calculus-based and Upper-Level courses.
  - "[…] courses with large positive shifts are those with an explicit focus on model building, small class sizes, and taught to elementary education and non-science majors."

Discussion

What might you change in your course/s to improve the epistemological beliefs of your students?

Citations

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