

PEDAGOGICAL CONTENT KNOWLEDGE

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<http://gse.rutgers.edu>

<http://paer.rutgers.edu/PT3>

<http://www.islephysics.net>

<http://paer.rutgers.edu/scientificabilities>

What should a physics instructor know? (replace physics with biology, chemistry, etc.)

WHAT IS MISSING?

Subject matter (concepts, rules, problem solving).
Methods of acquiring knowledge - how do we know what we know.

How human brain works.
How people learn.
How people work in groups.
How motivation is related to learning.

What should students learn in a physics course?
How do they reason?
What difficulties do they have?
How can we help them best?
How can we assess them?
What equipment do we need?
What software is available?
How to structure the curriculum ?

Pedagogical Content Knowledge

Lee Shulman, 1987

The category of teacher knowledge most likely to distinguish the understanding of a content specialist from that of the pedagogue.

Elements of Teacher Knowledge

Content knowledge

Knowledge of

- concepts;
- relationships among them;
- **methods of acquiring and applying knowledge**

Pedagogical content knowledge

Orientation towards teaching
Knowledge of:
curriculum;
student difficulties;
effective instructional strategies for a particular concept;
assessment methods

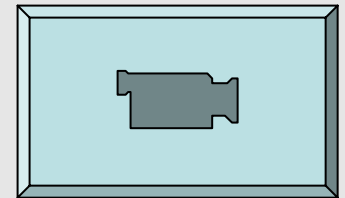
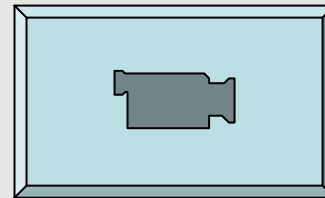
Pedagogical knowledge

Knowledge of:

- brain development,
- cognitive science,
- collaborative learning,
- ...

Physics PCK: CURRICULUM

Knowledge of physics curricula (the sequence of topics that allows a student to build the understanding of a new concept or skill on what she or he already knows, and what topics are better suited to build certain scientific abilities).



Physics PCK: STUDENT IDEAS

Knowledge of student difficulties (student ideas, recourses, facets, or difficulties or their interpretation of physics).

Internal force

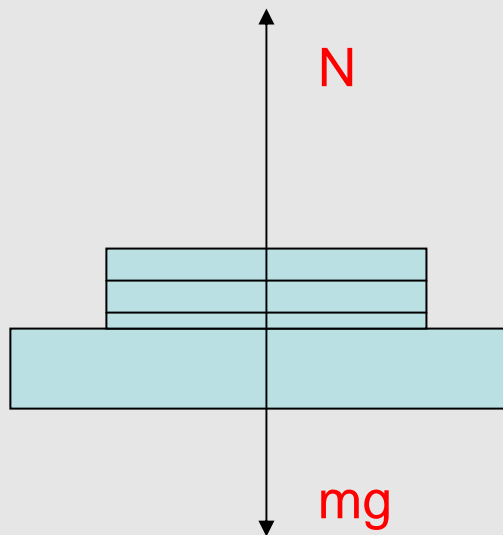
Acquired force

Force of gravity

Force of push or pull of animate on inanimate

Physics PCK: LANGUAGE

Knowledge of effective instructional strategies for a particular concept (what specific methods or specific activity sequences make student learning more successful).



Newton's
3rd law
forces?

~~mg~~

$$F_{\text{Earth on object}} = F_{\text{E on O}}$$

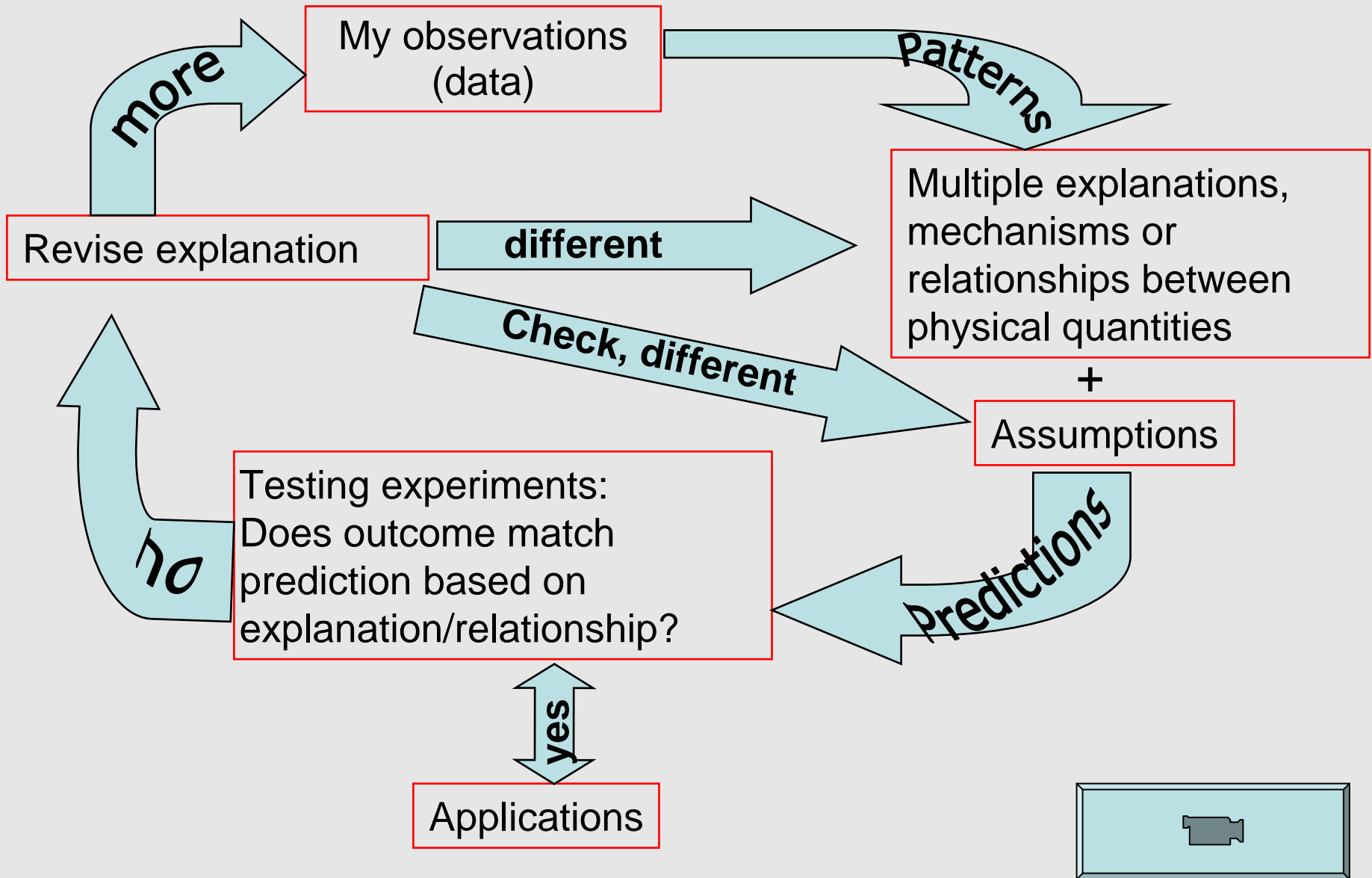
~~N~~

$F_{\text{S on O}}$

Student Reasoning

- Observing, representing, finding patterns, relating, making sense, explaining, predicting, testing, revising.
- Inductive and hypothetico-deductive reasoning

Curriculum: Investigative Science Learning Environment



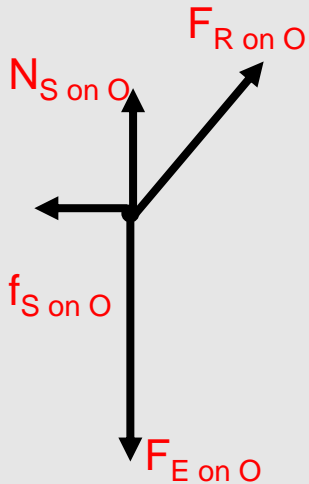
Physics PCK: ASSESSMENT

Knowledge of assessment methods (what are the ways to assess student conceptual understanding and acquisition of problem solving and general scientific abilities).

Mathematical description.	Sketch a situation the equation might describe.	Write in words a problem for which the equation is a solution.
$900 \text{ N} - (50 \text{ kg})(9.8 \text{ m/s}^2) = (50 \text{ kg}) v^2 / (12 \text{ m})$		

Assessing PCK

- Ms. Bante's students are learning Newtonian dynamics and are solving the following problem: An unlabeled free-body diagram for an object is shown on the left. Sketch and describe in words a process for which the diagrams might represent the forces that other objects exert on an object of interest.



She hears one of the students say: “There is a mistake in the diagram, the upward vertical force should be the same as the downward arrow”.

1. Do you agree with the student? Explain your answer.
2. How would you respond to this comment in class? Provide a possible scenario.
3. If you were to use student's idea a hypothesis to test, what testing experiments would you design?
4. How would you engage your students in a similar activity?
5. Why do you think the student made this comment?
6. What activities done in class prior to this activity could have contributed to his opinion?
7. What can you do as a teacher to help this student understand the complexity of the concept of normal force?

Helping future physics teachers build their PCK

Learn physics

Learn how people
learn

Build PCK

How can one acquire a cognitive skill?

Cognitive apprenticeship

**Independent
practice**

Slowly removing scaffolding

Providing coaching and scaffolding

**Contexts that model
proficiency**

If we had all time and money in the world

Physics Teacher Preparation Program

1. Future teachers learn **physics** through the same methods that they should use when teaching.
2. They acquire knowledge of how people learn and how they learn **physics**.
3. They learn ways to engage their students in actual **physics** practices.
4. Future physics teachers master the equipment technology that they can use in the **physics** classroom and acquire methods of updating their knowledge and skills.
5. They engage in **physics** teaching in environments that mirror the environments that we want them to create later.

Physics Teacher Preparation Program at Rutgers (EdM+certification)

Dreams come true...

- 45 graduate credits
- 2 years plus summer
- 1 semester of student teaching

- Content - undergraduate major (physics, engineering, chemistry)+ 6 credits of electives
- Pedagogy - 6 credits
- Policy – 6 credits
- Student teaching – 9 credits

- Process and reasoning of science/physics + PCK – **18 credits**

Course Sequence

Year 1

#1 *Development of Ideas in Physical Science**

Students use *ISLE* framework to reconstruct how physicists built the knowledge taught in our present courses and design/teach high school physics lessons in which students learn by following the original path of physicists. They learn what difficulties scientists had and how difficulties of our students can be explained historically.

#2 *Teaching Physical Science** **, oral exam

#3 *Technology in Science Education**

Students apply *ISLE* framework to design and practice learning cycles, combine them with the knowledge of student resources to plan units and lessons, learn to use technology and learn assessment methods.

* students teach a full lesson

**students plan a unit

Course Sequence

Summer 1

#4 *Research internship – science and teaching methods in X-ray astrophysics***

Students learn how to do research in X-ray astrophysics and observe high school students learning through *ISLE* in the same program

**students plan a unit

Course Sequence

Year 2

#5 *Teaching Internship seminar, ****

Students plan units and lessons during student teaching, design lessons of specific types, assessments instruments, and learn how to reflect on teaching practice.

#6 *Multiple Representations in Physical Science, **, oral exam**

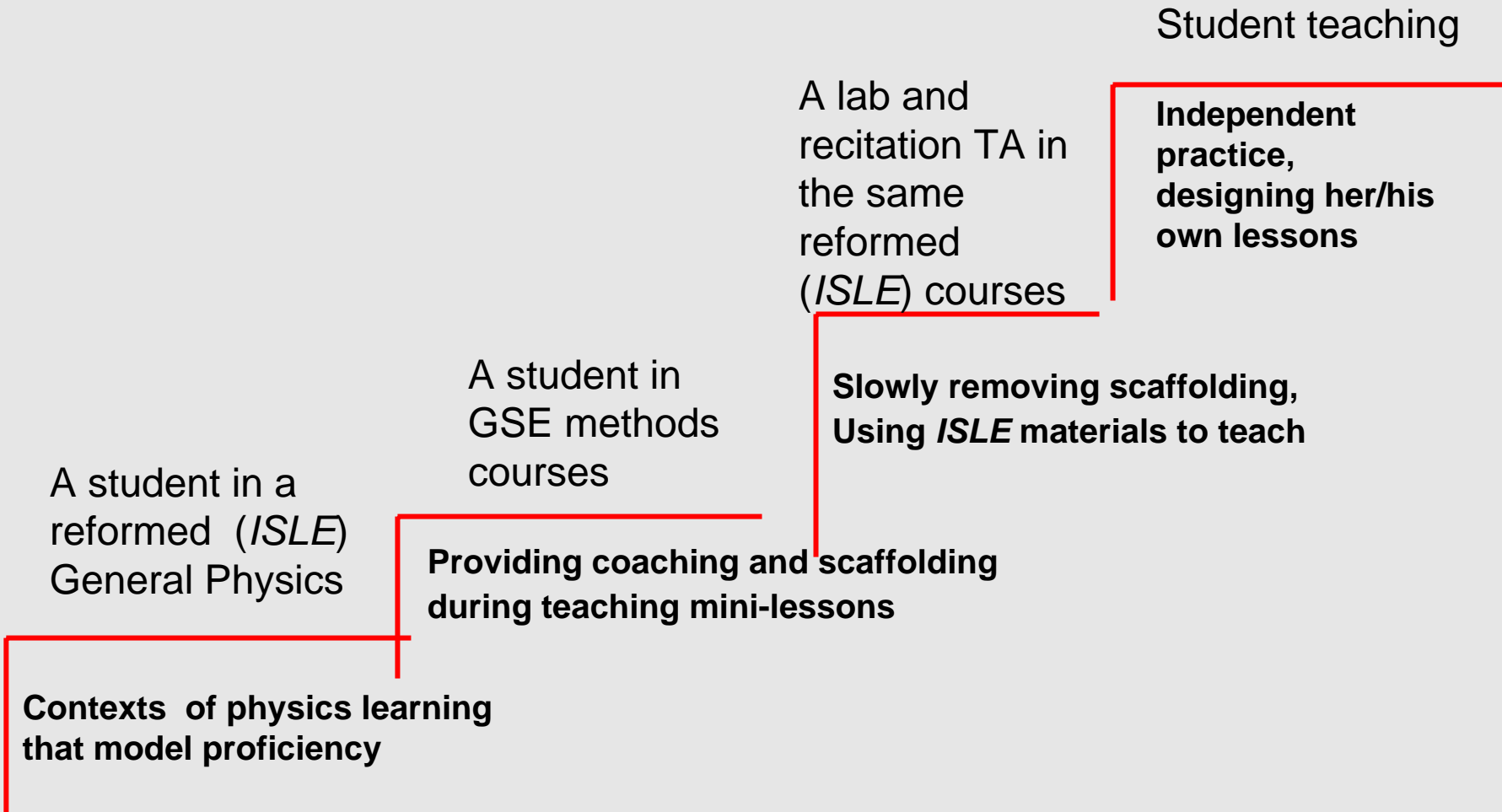
Students learn how to use cognitive strategies and scientific reasoning to enhance student problem solving in a physics course, apply technology.

*students teach a full lesson

**students plan a unit

Total in the program: teach in class 5 lessons and plan 5 different units; at the end of each semester every student receives copies of everyone's materials

Cognitive Apprenticeship



EXAMINIG COURSE SYLLABI

EXAMINE ONE OF THE SYLLABI CAREFULLY AND
PREPARE TO ANSWER THE FOLLOWING QUESTIONS:

1. WHAT ASPECTS OF THE *PCK* OR PHYSICS *CONTENT* KNOWLEDGE DOES THE COURSE ADDRESS?
2. HOW IS *COGNITIVE APPRENTICESHIP* EMBEDDED I
N THE COURSE?
3. HOW IS *FORMATIVE ASSESSMENT* EMBEDDED IN THE
COURSE?
4. HOW IS *MASTERY LEARNING* IMBEDDED IN THE
COURSE?
5. HOW IS *INQUIRY* EMBEDDED IN THE COURSE?

What do you think a person needs to know and be able to do to be a good physics teacher?

- Content
- Organization
- Fun

What do you think a person needs to know and be able to do to be a good physics teacher?

- Before the program, I thought that a good physics teacher just needed to have the **content knowledge**.
- Being in the program had changed that. A good physics teacher needs to have the **pedagogical knowledge** as well as the content knowledge, and the content knowledge has to go far beyond just the level being taught.
- A good physics teacher needs to understand **how students learn**, how they **construct concepts**, and needs to plan lessons with that in mind. She needs to understand **what will facilitate learning** of the most difficult, abstract concepts in physics.
- A good physics teacher needs to **anticipate student difficulties** with certain ideas in physics, and also **plan** with that in mind.
- A good physics teacher teaches students the **process of scientific investigation** – this is what they will take with them years after the class is over.

Make a list in order of importance of what you have learned in the program, separating into knowledge and skills

Knowledge

- My knowledge of physics itself (even though I know it still has a long way to go).
- My understanding of how scientists construct their own knowledge.
- My understanding of how students learn.

Skills

- I have learned how to not give away all the answers to students, so they can gain their own understanding.
- I have learned (I think...) how to keep student's attention in the subject matter.
- I have learned how to write a unit plan, plan a lesson and teach a lesson.
- I have learned how to design a test that probes a student's true understanding of the material and creativity as an experimenter.

Quantitative Results

Graduates of the physical science program

2003 - 1

2004 - 5

2005 - 7

2006 - 7

2007 - 5

2008- 8

Present High School and Middle School (1) Teachers

2003 - 1

2004 - 5

2005 - 5

2006 - 6

2007 - 5

In-service high school and middle school teachers who went through the same masters program (without student teaching)

2003-2007 - 13

Outcomes

Answer the following questions as completely as you can. Drawing your own diagrams will help.

1. Part of the early Greek geocentric model of the universe was that the stars were on a 'celestial sphere' that spun completely around the earth every day. *Explain* why this naturally led the early Greeks to the conclusion that the universe was finite. Draw a diagram.

2. The observation that the Sun appears to move through the stars over the course of the year (as seen just before sunrise) is explained by the model of the earth revolving around the sun. Explain how this model accounts for this observation. Draw a diagram.

3. Explain why (you may use drawings to help you explain) the model that the sun is very far away from the earth means that all the sun rays striking earth are basically parallel to each other.

4. You and a friend are walking in an open field and you see a tree that is very far away. You happen to have with you a protractor, a meter stick and a calculator. Explain how you would estimate the distance to the tree using the parallax method. Draw a diagram.