Developing Expertise in Physics: Solving the Problem

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KSU PER

- "Physics is a performance art."
  - - Anonymous Student

What I'm Going to Talk About

- Students' Views & Practices
- Representational Fluency
- Problem Difficulty

Students' Views & Practices

Beliefs about the Nature of Physics Knowledge

Hammer Variables	Expert-like	Novice-like
Independence	Learns independently, believes in their own need to evaluate and understand	Takes what is given by authorities (teachers, text) without evaluation
Coherence	Believes physics needs to be considered as a connected, consistent framework	Believes that physics can be treated as separate pieces
Concepts	Stresses understanding of underlying ideas	Focuses on memorizing and using formulas

Hammer, 1996

Colorado Learning Attitudes about Science Survey - CLASS

- Beliefs — It is possible to explain physics ideas without mathematical formulas.
- Attitudes — I enjoy solving physics problems.
- Expectation — I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.
- Practices — When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.

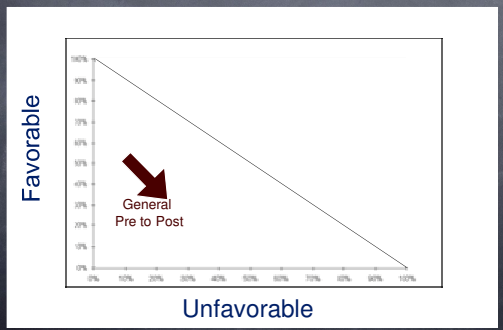
Item #6: Knowledge in physics consists of many disconnected topics.

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

Favorable | Unfavorable

Adams, et. al., 2006

MPEX



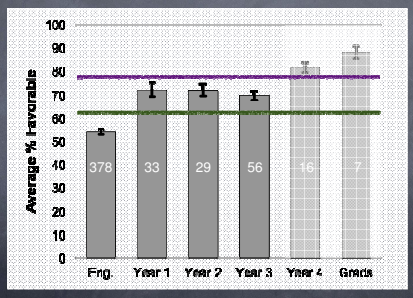
How do views change during undergraduate study?

- CLASS Survey
- Interviews
- Problem-Solving

Study Design

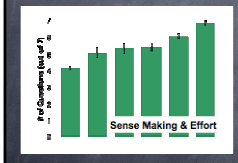
# Students		Courses Surveyed	Fall 2004	Winter 2005	Spring 2005	Fall 2005	Winter 2006	Spring 2006
Eng.	378	2A *Mechanics for Engineers*						
Year 1	33	4A *Newtonian Mechanics*					Pre &Post	
		4B *Fluids, Waves & Thermo.*						
Year 2	29	4C *Electricity & Magnetism*						
		4D *Optics, Special Relativity*						
		4E *Quantum Physics*						
Year 3	56	100A *Electricity & Magnetism*						
		100B *Electricity & Magnetism*						
		100C *E&M Elective*						
		130A *Quantum Mechanics*						
Year 4	16	130B *Quantum Mechanics*						
		200A						

Overall CLASS Score

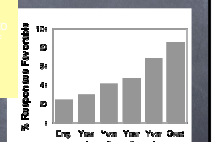


Gire, et. al., 2009

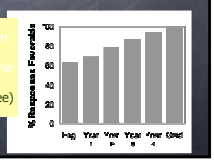
Sense Making & Effort



"In physics, it is important for me to make sense out of formulas before I can use them correctly." (Agree)



"There are times when I solve a physics problem more than one way to help my understanding." (Agree)



Gire, et. al., 2009

Problem Solving Categories

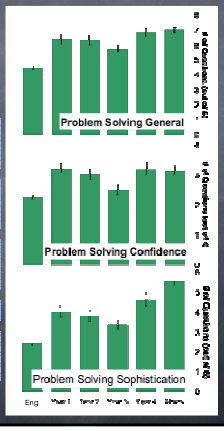
After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

I enjoy solving physics problems.

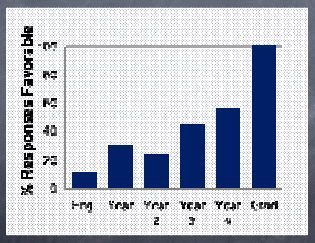
I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.



Gire, et. al., 2009

Plug-n-chug

"When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values." (Disagree)



Gire, et. al., 2009

Comments about Plug-n-Chug

Zoe:	Umm, number eight when I first start to learn a problem or a new concept and I'm unclear about it I'll try and do this, but if I'm really well versed and I understand it completely then I'll start doing, like I won't look for the equation, I'll like think about the problem itself and what they're asking me for and.. like for kinematics everyone goes to umm like, umm PE to KE I don't look at the equations, I start like ok well this object is gaining kinetic energy as it's losing kinetic energy and it kinda sets the problem for what its doing...
Interviewer:	Ok.
Zoe:	And then like on now what equations do I use or what would make sense in this problem, whereas if I didn't know I'd be like ok well I know they are asking for GPE ahh and kinetic energy, and so I try an fit it together...
Interviewer:	Ok.
Zoe:	So it depends on umm, how well I understand the concepts and how well they apply.

Gire, et. al., 2007

More Comments on Plug-n-Chug

Hoban: Yeah, I try to do that whenever I can.
It really depends on the problem. Like some problems it's obvious they just want you to plug into a formula, but in some it's not so obvious and you just have to think about it and so and with those it's just it's more thinking like cause a lot of the problems are just geared to plugging into the equation, you just put the pieces together and solve it ... but for other ones, it's… you can't just plug it in and work it that way, you have to think about it some

Gire, et. al., 2007

Summary of Views

- Views don't change much during first 3 years
- Views of physics majors' more favorable than engineering peers
- Some views related to problem solving less favorable in junior year
- Students recognize that plug-n-chug is not the same as conceptual understanding yet they report extensive use of it

More Questions...

- What kinds of experiences help students develop more expert-like views?
- Are there other dimensions of views or problem solving practices that become more expert-like during undergraduate study?
- Can we help students to use conceptual reasoning more often throughout the physics curriculum?
- Are these results representative of all physics programs?
- Do views get more expert-like in the senior year? Why might that be expected?

Framing

"proverbial 'hats' or 'glasses' we don as we take on a variety of identities or perspectives in dealing with different situations."

Resources

knowledge as fabricated

knowledge as transmitted

knowledge as free creation

Shaffer (2006)
Hammer, et. al., (2004)

Framing in Physics: Student vs. Professional

Student	Professional
Problems are well-structured assigned by instructor	Problems may be ill-structured, often identified by oneself
Solutions are known, short	Solution may be unknown, long
Relevant knowledge-based is expected to be narrow	Relevant knowledge-based understood to be broad
Mostly low-stakes	Many high-stakes
Presentation de-emphasized	Presentation important
Connections mainly identified by instructors	Re-representing relationships and making new connections

Visualization

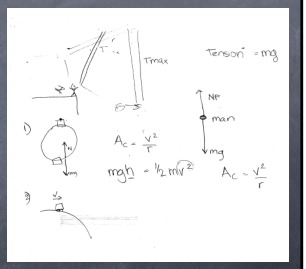
"I'm a very visual person."

"So if I can't picture the movement I'm gonna have problems which is why upper division scares me because apparently you have to stop picturing movement or you can't picture it or something"

"Umm, first I drew a diagram...because I always do that...just to visualize it. It's a lot easier if I can visualize it."

"I picture you just, like, holding a ball and then, letting go, and then just falling, yeah, straight down."

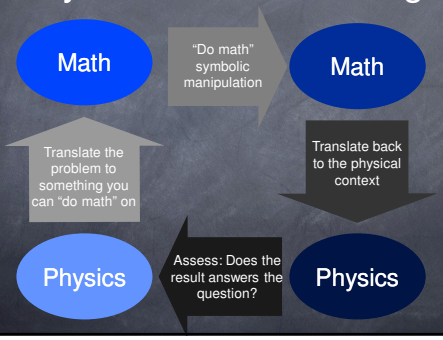
"...and they have a picture which is good because, for me I don't think just plugging and chugging for equations is like really understanding physics."



How do students' use of representations develop?

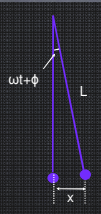
Representational Fluency

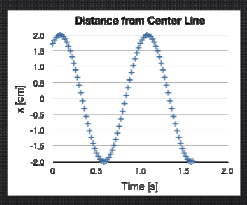
Toy Model of Physics Problem Solving



What is "Representational Fluency"?

Distance from center, x [cm]	Time [s]
1.7	0.0
1.5	0.2
-0.8	0.4
-2.0	0.6
-0.4	0.8
1.7	1.0
1.5	1.2
-0.8	1.4
-2.0	1.6





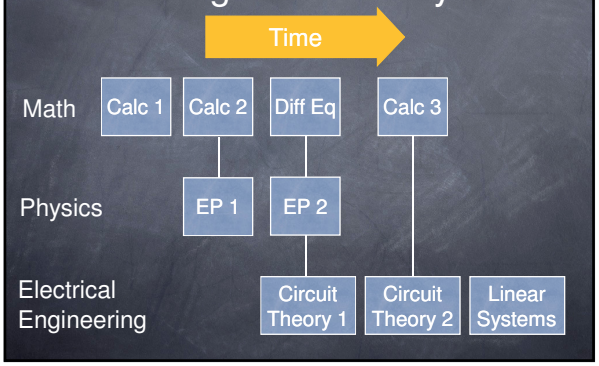
$x = L\sin(\omega t+\phi)$

Solving Problem in Multiple Representations

- How do students develop representational fluency?
- What kinds of difficulties do students encounter when solving problems in multiple representations?
- What kinds of scaffolding are useful in helping students overcome those difficulties?

Dong-Hai Nguyen

Longitudinal Study



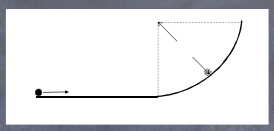
Data Collection

Problem Solving Interviews
n=20 EP1 students
EE/CSE majors
1 2 3 4

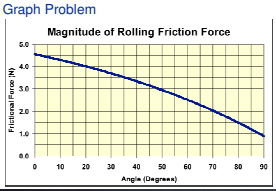
Problem Solving Interviews
n=15 EP2 students
EE/CSE majors
1 2 3 4

Focus Group Interviews
n=26 EP1 students
Engineering majors
1 2 3 4 5
Control
Treatment 1
Treatment 2

Example Interview Problems



Graph Problem



Equation Problem

$$F_{roll}(\theta) = -0.78^{2} - 1.2\theta + 4.5$$

General Comments about Individual Interviews (Spring & Fall 2009)

- Students were able to solve problems with hints
- Students initially had trouble invoking integral = area under the curve
- Students had difficulty coordinating geometric and algebraic modes of thinking
- Little evidence for integration = accumulation

Focus Groups Transfer Task

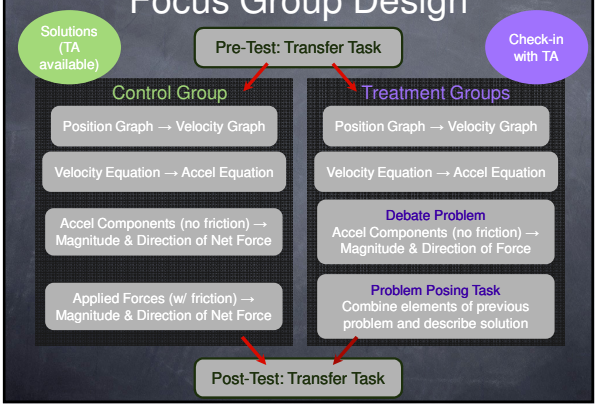
- A constant force F_B is applied on a 3.00 kg block moving across a horizontal floor on which an xy coordinate system is drawn. The coefficient of friction between the block and the floor is 0.15. The block's x and y position (in meters) as a function of time is given by

$x = 3t^2 - 5t - 7$ $\quad y = -4t^2 + 6t + 3$

- Find the magnitude of force F_B and the angle it makes relative to the positive axis.

Key Elements:
- ✔ Calculating acceleration components from position
- ✔ Finding acceleration from components
- ✔ Using Newton's 2nd Law
- ✔ Using trigonometry to find the angle from components

Focus Group Design



Focus Group 2 Results

Magnitude of Force

Graph	Pre	Post
Control	0/10	1/10
Treatment	2/14	6/14
Fisher's Exact Test	0.33	0.09

Equation	Pre	Post
Control	0/10	2/10
Treatment	2/14	10/14
Fisher's Exact Test	0.33	0.02

Angle of Force

Graph	Pre	Post
Control	1/10	2/10
Treatment	1/14	5/14
Fisher's Exact Test	0.51	0.26

Equation	Pre	Post
Control	1/10	4/10
Treatment	6/14	4/14
Fisher's Exact Test	0.09	0.29

Summary Representational Fluency

- An issue with representational fluency is coordinating geometric and algebraic reasoning.
- Research-based worksheets are showing some preliminary success.
- Manipulating students' framing for debate and problem posing helps students process/organize knowledge in different ways.

Problem Difficulty

Research Questions

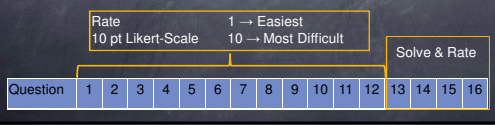
- How do students' and instructors' estimation of difficulty compare?
- How do students' estimation of difficulty depend on representation?
- How does the complexity of a problem affect its perceived difficulty?

ECR Project

- Developed a Survey of Problem Difficulty Estimation (SPDE)
- SPDE → Students & Instructors
- Developed a rubric for textbook style physics problems.
- Correlation between SPDE and the rubric

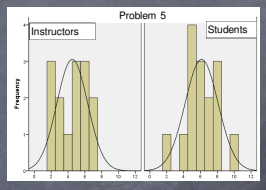
SPDE (Survey of Problem Difficulty Estimation)

- 16 Work & Mechanical Energy problems
  - ✓ Halliday, Resnick & Walker, 7th Ed.
  - ✓ Context Rich Problems
  - ✓ Numbers, symbols, equations, graphs, pictures
- Online Delivery



SPDE → Students & Instructors

- 15 Freshman Physics Majors
- "Estimate the difficulty"
- 14 Instructors
- "Estimate the difficulty for a student"

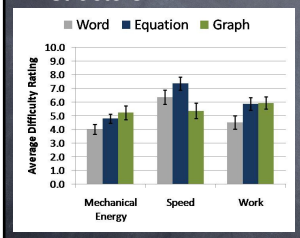


Independent Samples Mann-Whitney U Test

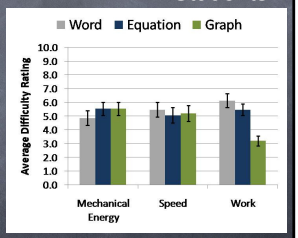
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
P-value	.74	.85	.95	.10	.04	.14	.01	.24	.16	.79	.01	.01	.00	.91	.55	.00
Median Student	2	2	2	5	6	5	4	6	6	6	5	5	4	6	6	3
Median Instructor	2	2	2	4	5	6	6	4.5	4.5	6	7	7	7	5	5	6

Estimations by Representation

Instructors



Students



Representation plays more of a role in instructors estimations of difficulty

Rubric - ECR Framework

- Exposition — Liz is a post-doc at Kansas State University conducting physics education research.
- Complication — Liz is seeking a tenure track position in a physics department.
- Resolution — Liz is invited to interview at the University of Memphis and her job talk is well received.

ECR & Physics Problems

- Expos

How much potential energy is stored in a spring with spring constant k = 170 N/m when it is compressed 5 cm?

- Complication — Spring with k = 170 N/m compressed 5 cm
- Calculate the potential energy

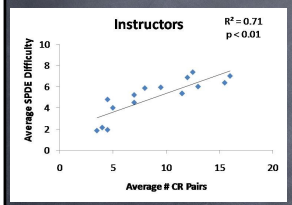
3 CR Pairs

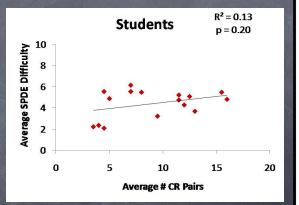
Complication
Resolution — What physics idea to use?
Definition of potential energy for linear spring
$U = \frac{1}{2}kx^2$

Complication
Resolution — Which numbers go with which variables?
k=170 N/m, x= 5 cm

Value of the potential energy

ECR & SPDE Correlation





Difficulty Estimation Summary

- Student and instructor estimation of problem difficulty can be quite different
  - ✓ No discernible global trend
  - ✓ Context rich problems → students estimate as easier
- Instructors' difficulty estimations rely more strongly on:
  - ✓ the number of steps in the solution
  - ✓ problem representation
  - than does students'.

Future Directions

- ➡Compare correct response rate with difficulty estimation & ECR score
- ➡Interviews with instructors and students to determine criteria for difficulty
- ➡Other physics topics

Overall Summary

- Physics majors' overall views about physics knowledge are fairly stable
- Framing may be an important aspect of developing expert-like views and representational competence.
- Different views progress differently - sense-making and problem-solving
- Coordinating geometric and algebraic reasoning is difficult for students - preliminary progress on a research-based worksheets
- Students' and Instructors' estimations of problem difficulty rely on number of steps and problem representation differently

References

Thank You

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