Presented at the 2007 American Association of Physics Teachers (AAPT) Annual Summer Meeting, Greensboro, NC

Session FF02, August 1, 2007
Auditorium I, 3:30 – 4:00 PM

- Why is physics worth teaching and learning?
- How could we sustain students' excitement for learning physics?

Even before the start of the course, 73% of students in one high-needs secondary school highlighted physics' real-world connection in the Colorado Learning Attitudes about Science Survey.

- What do high school students think learning physics does to their problem-solving ability? Their thinking ability? Their ability to make decisions using a process of reasoning? Their ability to use math to solve problems? What is the role of guided-inquiry hands-on learning activities in nurturing these four "higher literacy skills?" Could our students be recognized as co-creators of knowledge in the classroom and build on their existing knowledge?

In this session, participants will explore the findings from one physics educator's middle and high school web-enhanced applied technology, physics, and physics engineering technology classes.

The Gorilla in the Room: Physics?

Nathan Balasubramanian

Problem Space

Designing Learning (DL) & its two Components

Impact & Implications

Next Steps

Stop

Reflect

Think

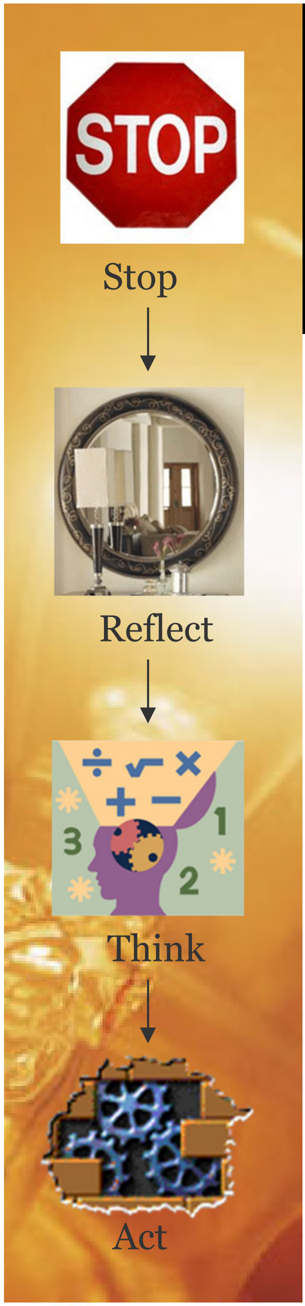
Act

Driving Questions

How did I get here?

1. Can we make schools **compelling** enough for students to want to **attend and achieve**?

2. How do we galvanize, nurture and sustain student **motivation** and **interest** in learning?

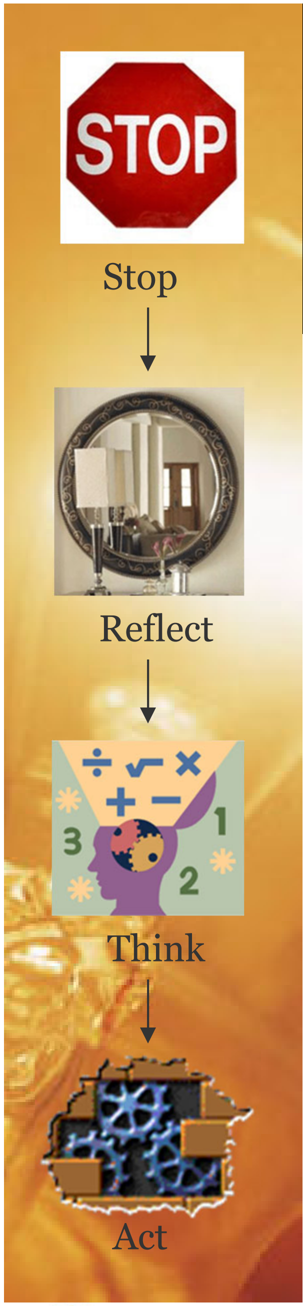


Driving Questions

How did I get here?

3. What instructional strategies would promote students' **conceptual understanding** so their interest and confidence increases?

4. With limited contact time scheduled for learning, what will it take to instill the necessary **discipline** in our students to take time and ownership for learning?



Now What?

Where do I want to go with this?

1. How can we promote *teaching for transfer*, when students use their learning and understanding from one subject (physics in our case) and apply it in other subject-areas and real-life situations?

Problem Space

- Did your school make Adequate Yearly Progress (AYP) in Reading? Math?
- 62% increased time for English &/or Math & 44% cut time from other subjects (*Center on Education Policy Study released July 25, 2007*)
- "Students learn too little in science" (p. 51) *Designs for Science Literacy*
- Teachers repeating the information presented in textbooks without understanding their real meaning stifle student motivation
- "Cookbook labs" from the textbook for hands-on learning have led to student complaints about science being boring and disconnected from real life (Gagné, 1997; Kokkotas et al., 1997)
- Teachers insufficiently prepared in the physical sciences has led to the neglect of these sciences (Asoko, 2000; Schickendanz et al., 1990)

Problem Space Continued

• "Chemistry is just like putting chemicals together and watching the reactions its (*sic*) instant gratification and I like it better" (HS Student)

• Teachers have few opportunities to confront students' incomplete understanding, false beliefs and naïve renditions of scientific concepts (Gardner, 1991)

• Concerns about students' problem-solving and critical thinking abilities (Reports from the *Program for International Student Assessment*, 2006, *Trends in Mathematics and Science Study*, 2006)

• This declining trend could threaten the economic welfare and security of the country (*Science and Engineering Indicators*, 2006)

Irony

• Individuals planning science and engineering careers make their decisions **early** and are quite **persistent** (Csikszentmihalyi & Schneider, 2000)

iLearn

Yet . . .

As early as 1869, Huxley (1901) observed that sciences taught through practical, hands-on activities help students hone their skills in *observation*, *inference-making* and *drawing conclusions* because they bring students' minds "directly into contact with fact" (p. 113).

CSAP → Graphic Organizer

A GRAPHIC ORGANIZER TO FACILITATE SYSTEMIC THINKING ACROSS SUBJECT-DISCIPLINES

READING	WRITING	MATHEMATICS	SOCIAL STUDIES	SCIENCE	TECHNOLOGY
R1 Challenge; Question; Purpose	W1 Challenge; Topic; Purpose; Thesis	M1 Challenge; Problem	SS1 Challenge; Topic; Theme	S1 Challenge; Question; Problem	T1 Challenge; Problem
R2 Skim passage; Connect to background knowledge; Activate schema; Make educated guess using context clues	W2 Pre-write; Brainstorm; Outline; Plan; Web	M2 Identify concepts	SS2 Identify key terms, Vocabulary; Isolate & classify variables	S2 Identify concepts; Make educated guess, Hypothesize	T2 Design brief; Specifications, including timeline
R3 Read passage; Process information; Look for key words, ideas, events; Reason	W3 Write rough draft	M3 Devise problem-solving strategy	SS3 Reason; Observe cause & effect relationships	S3 Reason; Identify cause & effect relation-ships; Select variables to control	T3 Explore multiple solutions; Select best & creative solution
R4 Visualize; Make inferences	W4 Revise draft; Make a case	M4 Use manipulatives; Carry out operations	SS4 Investigate; Seek & select source(s)	S4 Plan & experiment	T4 Implement solution & build model or prototype
R5 Identify important information & interpret	W5 Edit draft	M5 Review work done; Illustrate, plot & graph; Analyze graph & data	SS5 Analyze & verify findings	S5 Analyze results & graph relationships	T5 Test & evaluate prototype or product
R6 Summarize & synthesize; Check if purpose accomplished; Communicate & justify solution using own words	W6 Share & communicate using final draft	M6 Verify reasonableness of result; Communicate solution	SS6 Summarize & synthesize; Check if purpose accomplished; Communicate; Predict	S6 Verify reasonableness of result; Check if purpose accomplished; Communicate findings of experiment	T6 Reflect on product & process; Modify design; Share & communicate final design

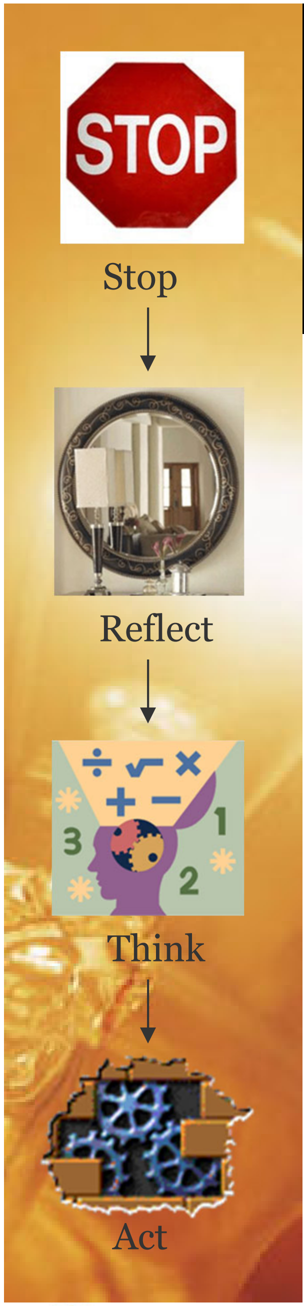
Designed and developed by Nathan Balasubramanian April 17, 2004

Games and Simulations

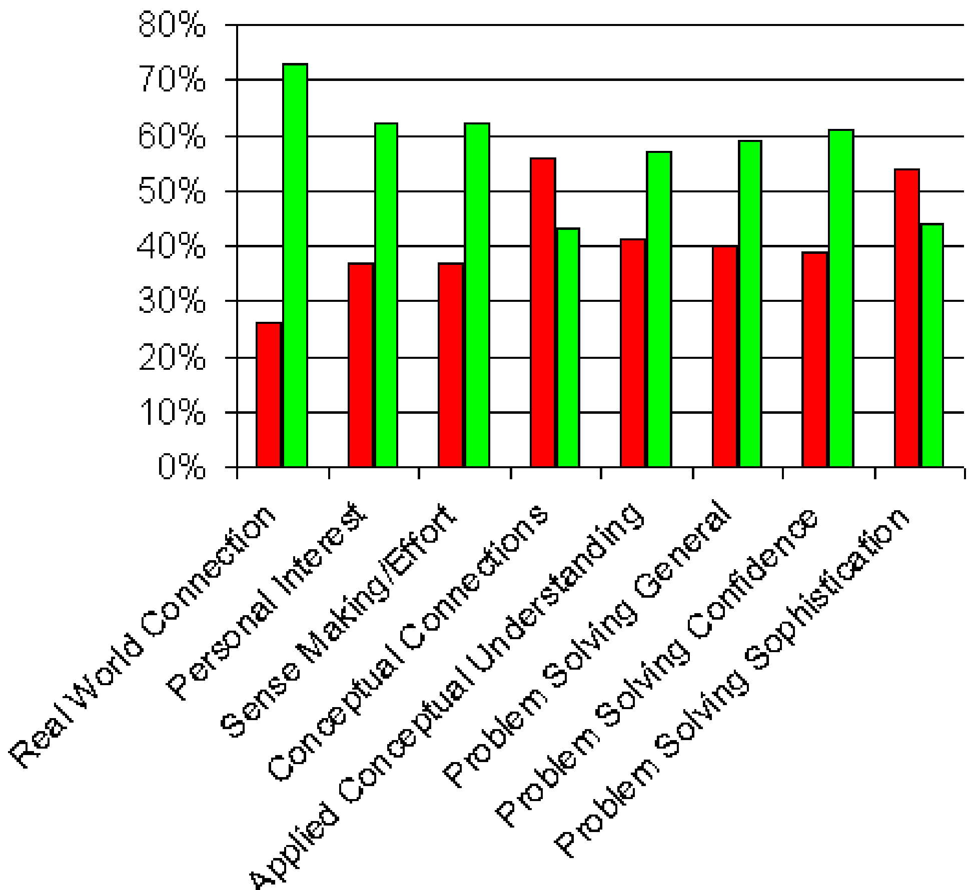
"Middle school students from all groups, disaggregated by gender and ethnicity, showed significant learning gains after playing the challenging Nobel games.

We recommend five guidelines that are necessary for games and simulations to be meaningfully integrated into classrooms."

Balasubramanian, N. & Wilson, B. G. (2006). Games and Simulations, In C. Crawford et al. (Eds.), ForeSITE, Volume One, 2005, *Proceedings of Society for Information Technology and Teacher Education International Conference 2006*. Chesapeake, VA: AACE (p. 2).
https://www.researchgate.net/publication/228979011_Games_and_simulations



HS Students' CLASS Snapshot – (Insert calc.-based Phy. I course*)



(N = 109)

TOTAL Disagree
TOTAL Agree

(N = 397)

Group	Pre (%)	Post (%)
RW	72	65
PI	67	56
SM/E	73	63
CC	63	55
ACU	53	47
PSG	71	58
PSC	73	58
PSS	61	46

*Adams, W. K., Perkins, K. K. et al. (2006) in PRST

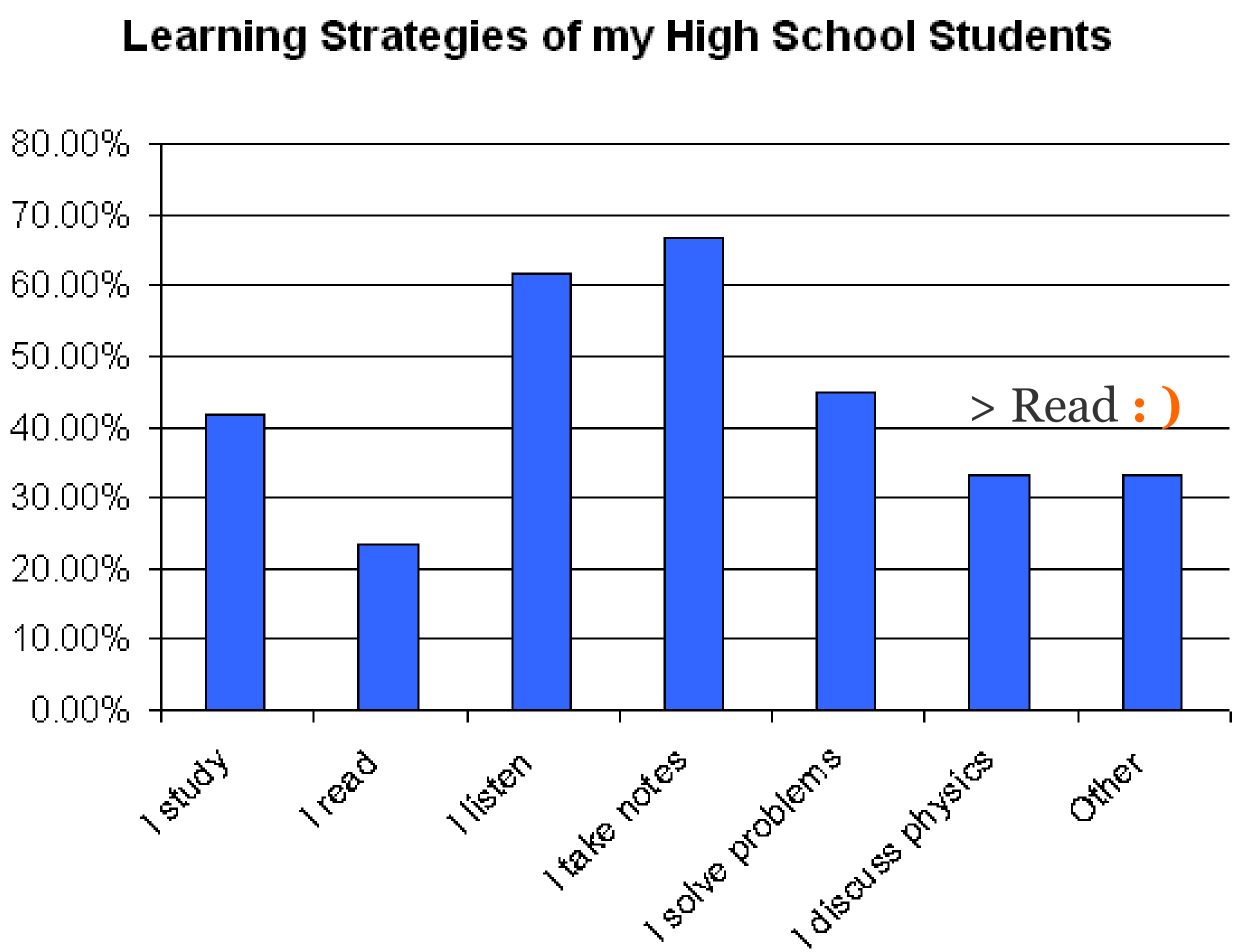
My Students' Learning Strategies

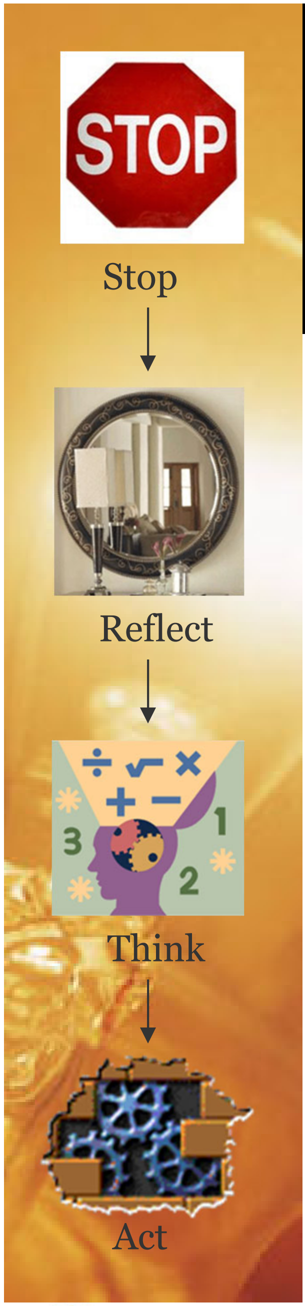
Stop

Reflect

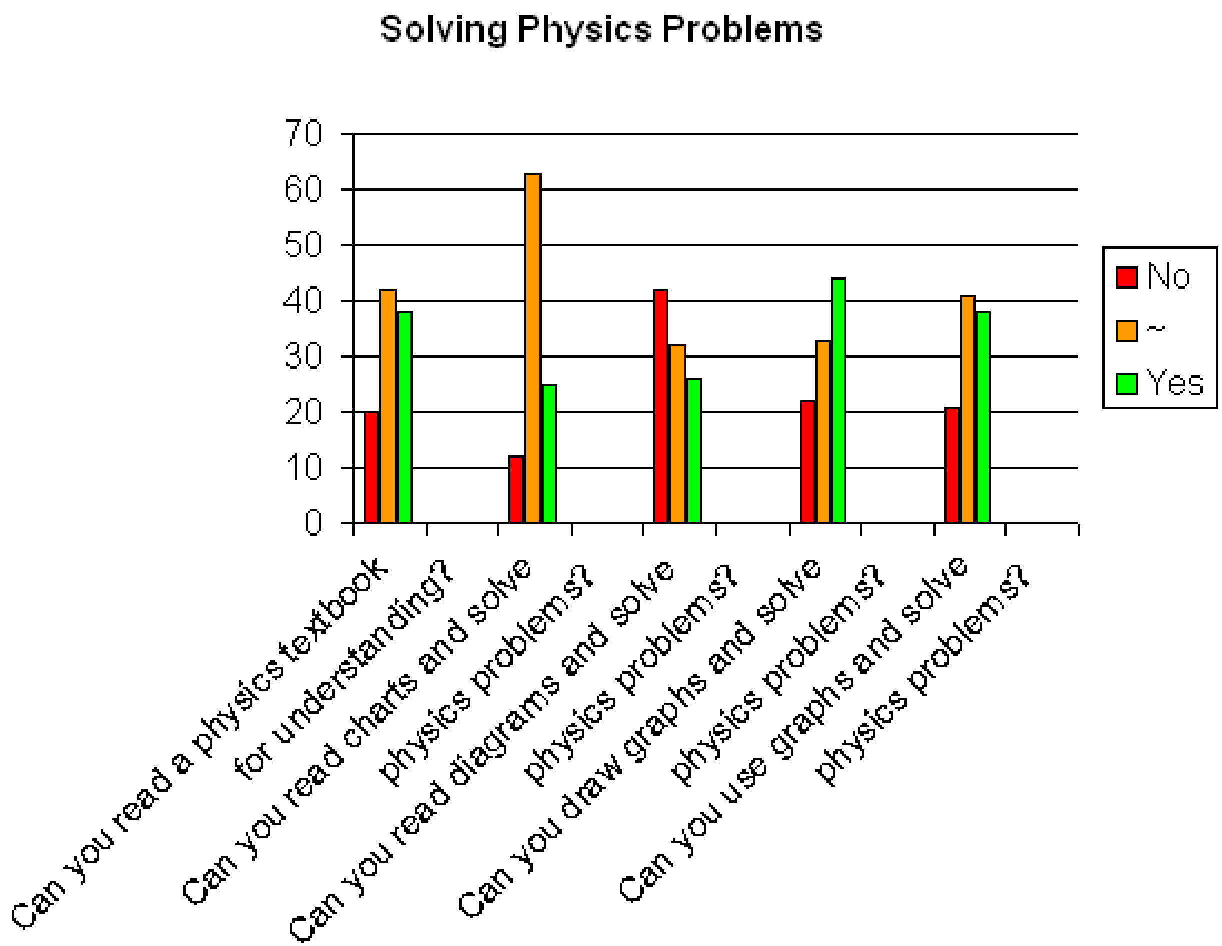
Think

Act





Ability to Solve Physics Problems



Short Video Clip

Stop

Reflect

Think

Act

Stop

Reflect

Think

Act

Why am I teaching physics?

It **had to be** beyond getting my students to do well in the

- IB (International Baccalaureate)
- Cambridge IGCSE
- CSAP (Colorado Student Assessment Program)
- AP (Advanced Placement) Physics

Examinations

Where does the “gorilla” fit in?

Stop

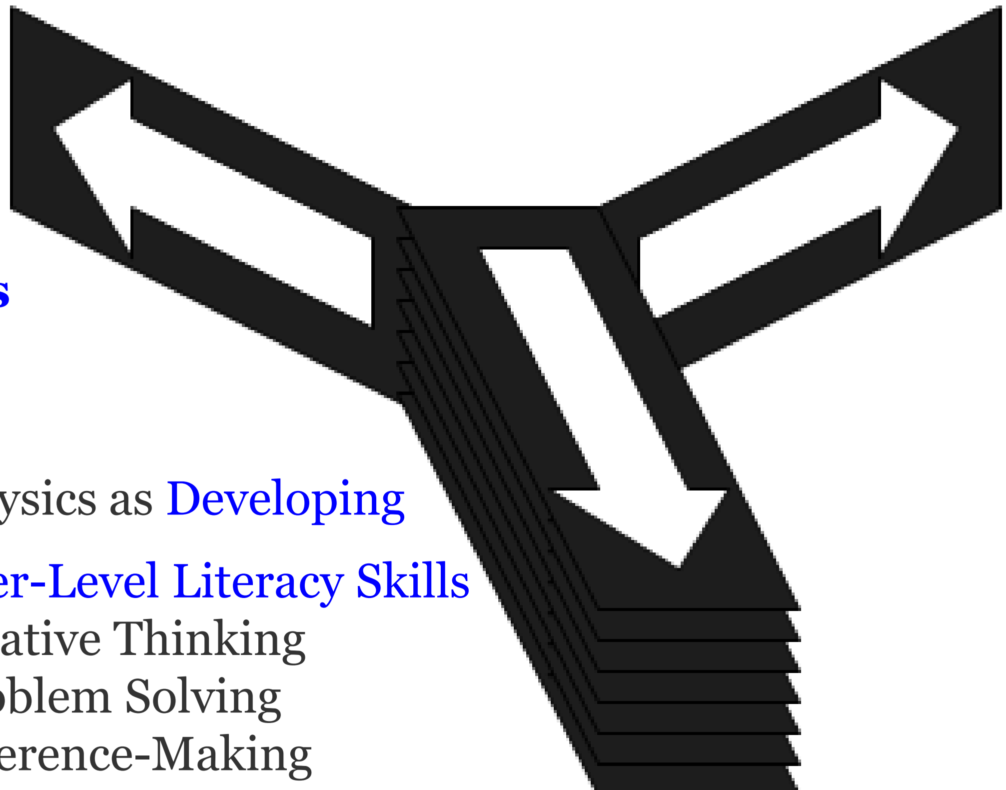
Reflect

Think

Act

Exciting & Fun Physics Demonstrat-ions

Hit & Miss



Punishing Math-based Algorithms Strategies

Only a Few Determined Individual’s Persevere

Position Physics as Developing

Students’ Higher-Level Literacy Skills

1. Creative Thinking
2. Problem Solving
3. Inference-Making
4. Mathematical Reasoning
5. Visualization/Modeling

Intentional & Empowering

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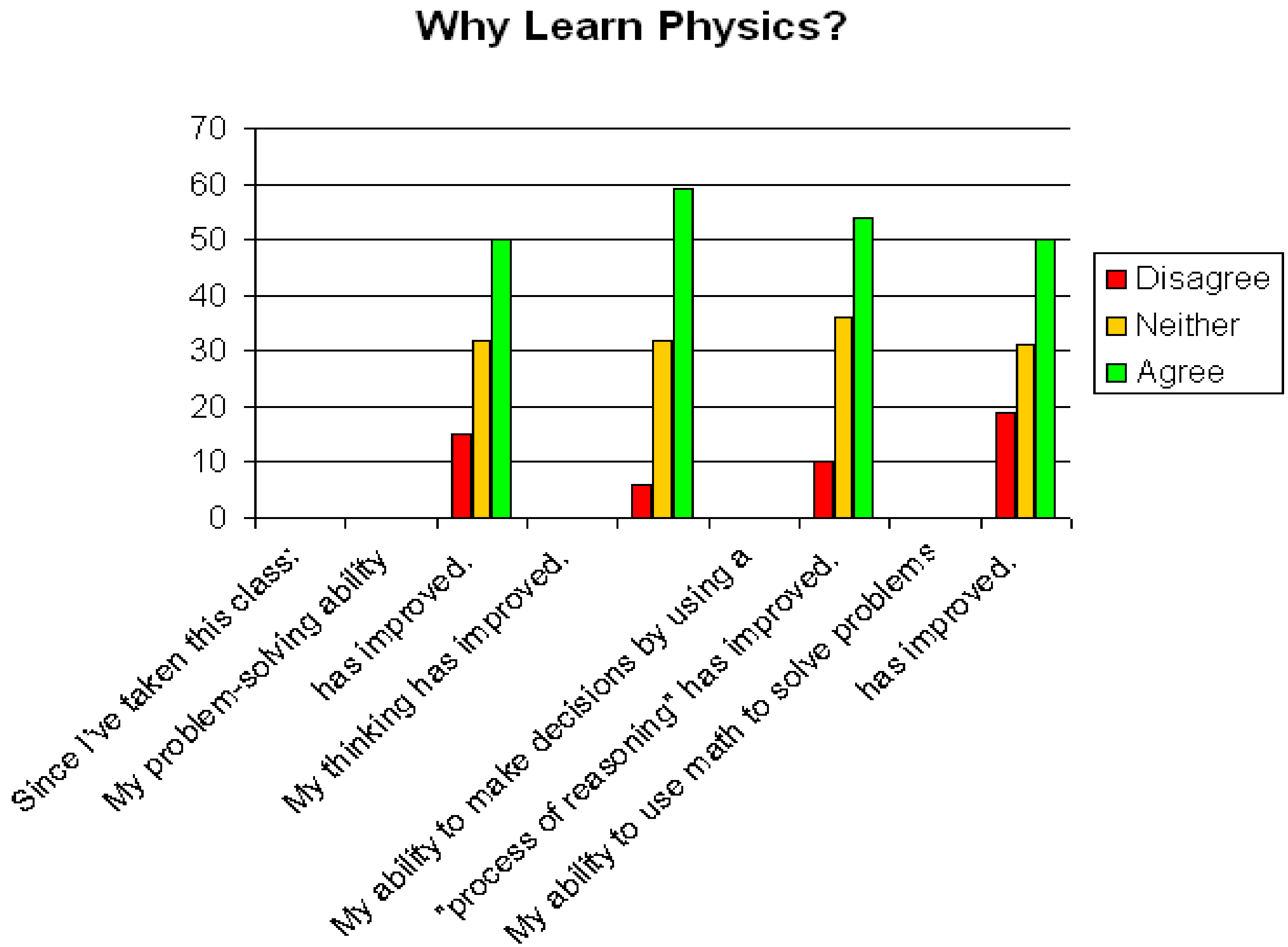
Why Learn Physics?

Stop

Reflect

Think

Act



Instructional Activities

My Typical Classroom Practice:

Kindle
Zeigarnik Effect

Pre-write & Pretest

Challenges – Hands-on

Games & simulations

Questioning
& Feedback

Monetary Monitoring

Debrief Pretest

Preview Exemplars

Instruction

Direct Instruction

Hands-on Investigation

Review/Summary

Summative Assessment

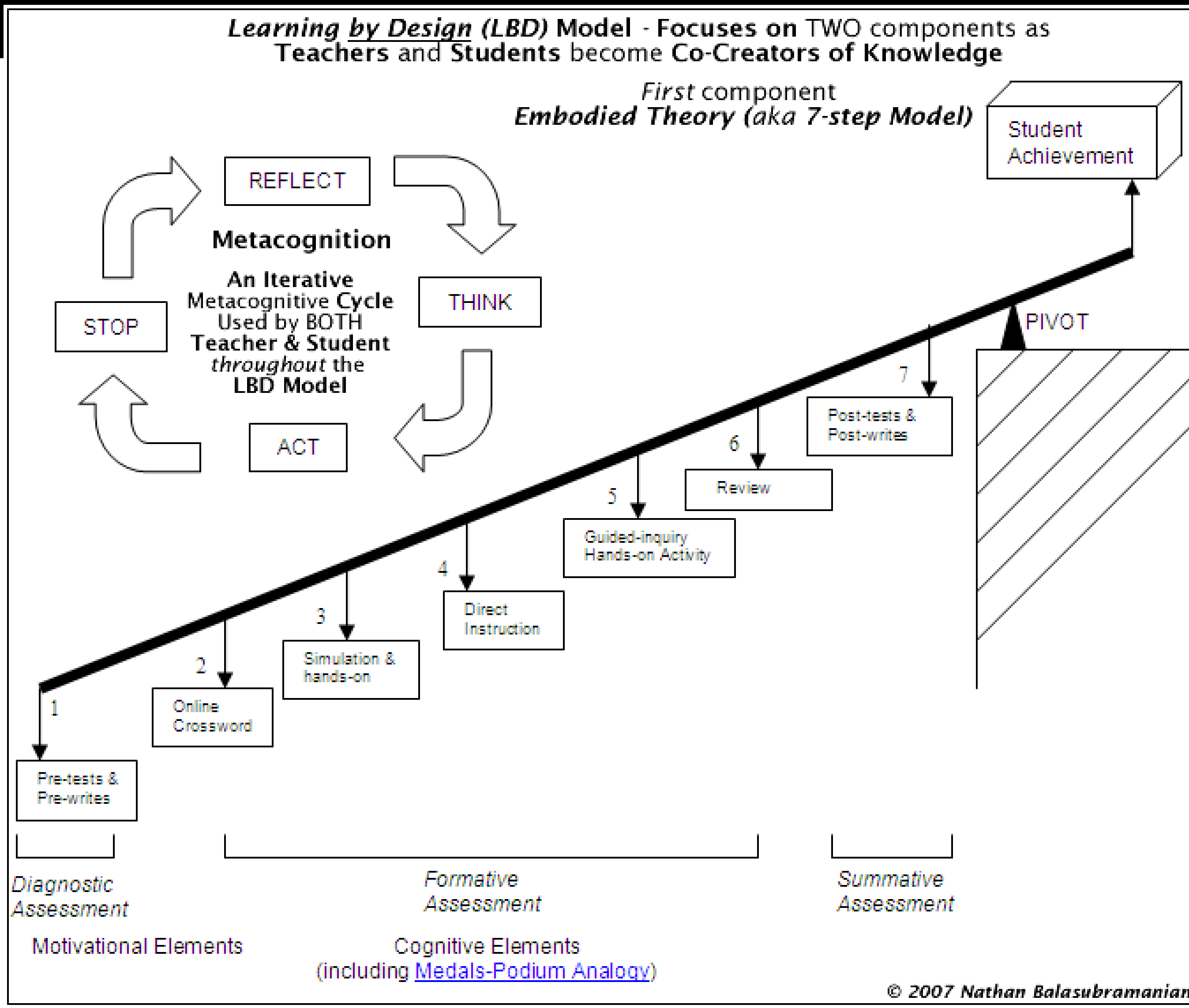
Designing Learning–1st Component

Stop

Reflect

Think

Act



Stop

Reflect

Think

Act

Higher-level Literacy Skills

Here's how the five *Higher-level Literacy Skills* are currently defined:

Caveat: Definitions are limiting.

Regardless, we need them in order to understand & actively teach these important constructs.

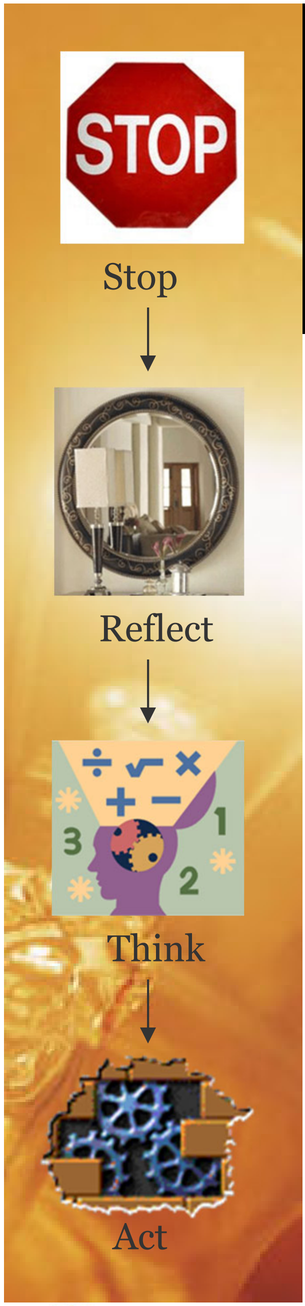
Additionally, we need to structure the activities/problems/challenges so that out students learn:

a. Team-building skills
b. Communication skills
c. Presentation skills

Augmented Version of AP Physics B Exam

Students' Content Mastery + Cognitive Skills (i.e., memory, analytical, creative, & practical thinking

Higher-level Literacy Skills
Critical Thinking



Critical Thinking = Purposeful Reasoning + Reaching Valid Conclusions

Example 1: Illustrative Inquiry Scenario

I. Using only the materials provided, can you make the Piezo Buzzer beep?

- 1 fruit, 1 vegetable, 1 buzzer, 2 coins, 2 galvanized nails and 3 wires

II. Investigate the electrical behavior of the liquid in three beakers and compare and contrast your "fruit batteries" with the behavior of liquid in the previous investigation.

III. Can you make a light bulb work with only 1 cell, 1 light bulb and 1 wire?

Stop

↓

Reflect

↓

Think

↓

Act

Higher-level Literacy Skills
Creative Problem Solving

Problem Solving = Overcoming Obstacles + Achieving Goals

Example 2: Illustrative Inquiry Scenario:

Using the choices (tank shell, golf ball, baseball, bowling ball, football, pumpkin, adult human, piano or Buick) provided in the Projectile Motion Simulation (http://phet.colorado.edu/web-pages/index.html)

- Determine the angle at which your launched object hits the target?
- Can you now hit the target by launching it at an angle that is completely different from the original angle?
- What angle should you launch a projectile to make it travel the farthest distance, with and without air resistance?

Stop

Reflect

Think

Act

Higher-level Literacy Skills Problem Solving Continued. . .

Problem Solving = Overcoming Obstacles + Achieving Goals

*Follow-up Hands-on Activity**

- Can you design and launch an air powered rocket* to fall into a bucket 5 m away, with and without carrying a payload?
- What are the variables you might control?
- What angle would you launch it there was a head wind (fan blowing from bucket) or tail wind (fan blowing from rocket launcher)?

*Students would have recognized they had to control angle, mass and launching force (height from where book dropped) to hit the target. Also, the angle of launch would change depending on head wind and tail wind due to differential air drags.

Stop

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Reflect

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Think

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Act

Higher-level Literacy Skills Illustrative Consequence

George's Version (unchanged from original):

The other day (Sunday, November 19, 2006), Sean and I were at the Denver Broncos and San Diego Chargers football game. We were sitting near the top of the sitting area and I posed a question to Sean. I asked him "If I were to through an object on to the flied to you think it would make it?" He said, "No," and I said I think you can. Then the next day we went to Mr. B's class, and we posed this question to him. Then we went on the computer and log on to a project title program, and created the same conditions. Conditions meaning the same height and distance we were at, at the game. We throw many objects at the same angle and made it on to the field on the computer. That proved that I could have thrown an object and made it on to the field throwing at a 45^{o} angle. 45^{o} angle was not the only angle we tryed we typed many different angle before we arrived at a 45^{o} angle. At the 45^{o} angle we were able to hit our object. (*sic*)

Stop

Reflect

Think

Act

Higher-level Literacy Skills Consequence Continued . . .

Sean's Version (unchanged from original):

Around 2 weeks ago George and I were at the Broncos and Chargers game. We were sitting near the seating areas top. George posed the question to me that "If we were to throw an object, the field, would it make it?" I did not think this was possible given our distance compared to height. George believed that you could in fact do so if you disregard wind resistance. Soon, after that we used a computer simulation to determine our height and distance from the field. Then we tested different angles until we determined that the ball would make it there if thrown from a 45^{o} angle.

- The field was only hit at 45^{o} angle but we tried many scenarios.
- We had to disregard are resistance and wind factor as well because the simulation would not account for this.
- Implementing air resistance, the object would not reach the field. The closest it would come would be at 28^{o} angle with air resistance.
- The wind was at our backs which should have pushed the object further. !!

Higher-level Literacy Skills Mathematical Reasoning

Stop

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Reflect

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Think

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Act

Mathematical Reasoning = Quantifying Variables + Supporting Results

Example 3: Illustrative Inquiry Scenario:

- Measure the mass of the six colored containers provided. The containers are filled with some unknown object.
- Look for a pattern among the masses of the six boxes and guess what might be accounting for the change in the mass of these containers.
- Explain (in your results) how this activity might be connected with a topic being studied in class*.

*Students had studies Electric Forces and Fields when they were given this activity to connect it with Millikan's Oil Drop Experiment in Modern Physics.

Stop

Reflect

Think

Act

Higher-level Literacy Skills Inference-Making

Inference-Making = Logical Reasoning + Informed decision-making

Example 4: Illustrative Inquiry Scenario:

IV. Using only two batteries, two light bulbs and no more than 4 wires:

- (i) Demonstrate how both light bulbs can be made to glow (ii) Demonstrate how both light bulbs might be made to glow at their brightest.

DRAW a circuit diagram of your arrangement and answer the following questions:

- What is the difference between (i) and (ii)?
- What do you think accounts for the difference in (i) and (ii)? [*Hint*: Think in terms of current, potential difference and resistance]

Higher-level Literacy Skills Inference-Making Continued . . .

Stop

Reflect

Think

Act

Inference-Making = Logical Reasoning + Informed decision-making

Demonstrate the difference by showing the different numbers on a meter (using a simulation and/or otherwise).

- Test: Unscrew one light bulb a little. What happens in arrangements (i) and (ii)

- Which of these arrangements would you choose to use in the headlights of your car. Why?

Stop

Reflect

Think

Act

Higher-level Literacy Skills Visualization/Modeling

Visualization = Pattern Recognition + Communicating to Diverse Audience

Example 5: Illustrative Inquiry Scenario:

• Create a multimedia video presentation to illustrate the difference between gravitational and electric potential

Sample Worked Example: Concluding Video in http://doers.us/electrostatics.htm

• Estimation Game in PhET http://phet-web.colorado.edu/simulations/estimation/launchEstimation.html

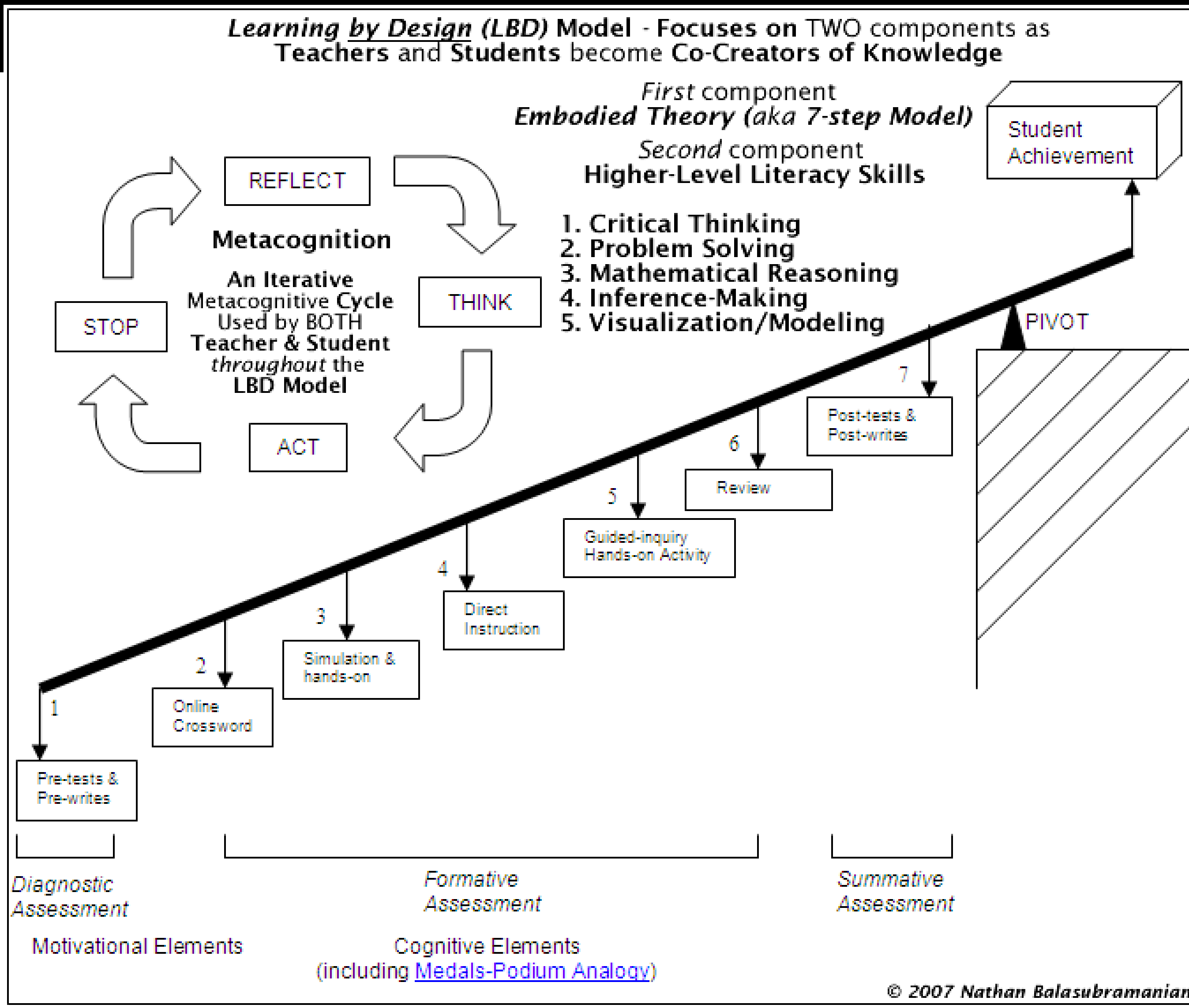
DL Model–With Both Components

Stop

Reflect

Think

Act



Stop

Reflect

Think

Act

Students' 1 word exit summary* of Physics Engineering Technology

Fun	Exciting
Interesting	Intriguing
Special	Experimentation
Tight	Physics
Easy	Extravagant
Powerful	Interesting
Cool	Challenging

*Not scientific, but inserted here as a mere indicator

Stop

Reflect

Think

Act

Honors students' reflections on the AP Physics B Experience

<table>
<tr><td>When we first found about the AP test, I wasn't thrilled. I'm glad now that I tried because it really was a challenge and I worked hard for it.</td><td>The AP test was a new experience and even though I don't think I did that well I like that I took the challenge to take the AP test. Thank you for making us try and take this challenge.</td></tr>
<tr><td>I will begin to say that I was really excited to work with you all year long . . . As far as my AP experience, it was difficult to do the multiple choice. But the free response was not too bad.</td><td rowspan="2">When I first got here, I did not know that much of physics vocabulary, but with your help I knew more. . .I liked the class of Regular Physics and I knew most of the subject we studied and I was happier when I moved to the Honors class and I was proud. Some of the questions we did in class were on the test ! ! !</td></tr>
<tr><td>I normally had fun in this class and think that the AP test was useful.</td></tr>
<tr><td>I think it was a big jump for me to take an AP Exam. I enrolled in Honors class. It took a lot to take the AP Exam. I believe it worked out well for me because I got a good taste out of it.</td><td>I thought I accomplished a lot for being in Honors Physics but I wished we could've moved at a faster pace so I could've done better on the AP Exam. This class was fun.</td></tr>
</table>

iLearn

Stop

Reflect

Think

Act

Teacher Self-Evaluation

	RTOP Score	RTOP_HS Avg. %	Teach.% of RTOP Max.	LPI %	LPI_HS Avg. %	CK %	CK_HS Avg. %	PK %	PK_HS Avg. %	T/SC %	T/SC_HS Avg. %
MT1	49	71	51	36	62	80	83	25	62	64	79
MT2	60	71	63	54	62	80	83	55	62	64	79
MT3	45	71	47	43	62	55	83	30	62	57	79
N = 3	**51**	**71**	**53**	**44**	**62**	**72**	**83**	**37**	**62**	**62**	**79**
ST1	54	71	56	50	62	75	83	45	62	57	79
ST2	81	71	84	82	62	95	83	65	62	93	79
ST3	65	71	68	68	62	75	83	55	62	71	79
ST4	64	71	67	25	62	100	83	85	62	71	79
N = 4	**66**	**71**	**69**	**56**	**62**	**86**	**83**	**63**	**62**	**73**	**79**
ET1	71	71	74	61	62	85	83	75	62	79	79
ET2	85	71	89	89	62	90	83	80	62	93	79
ET3	66	71	69	50	62	80	83	60	62	86	79
ET4	74	71	77	68	62	80	83	60	62	96	79
ET5	82	71	85	86	62	80	83	80	62	93	79
N = 5	**76**	**71**	**79**	**71**	**62**	**83**	**83**	**71**	**62**	**89**	**79**
SST1	80	71	83	71	62	100	83	70	62	93	79
SST2	82	71	85	86	62	90	83	80	62	86	79
N = 2	**81**	**71**	**84**	**79**	**62**	**95**	**83**	**75**	**62**	**90**	**79**

Piburn, M, & Sawala, D. (2000). Reformed Teacher Observation Protocol (RTOP) Reference Manual

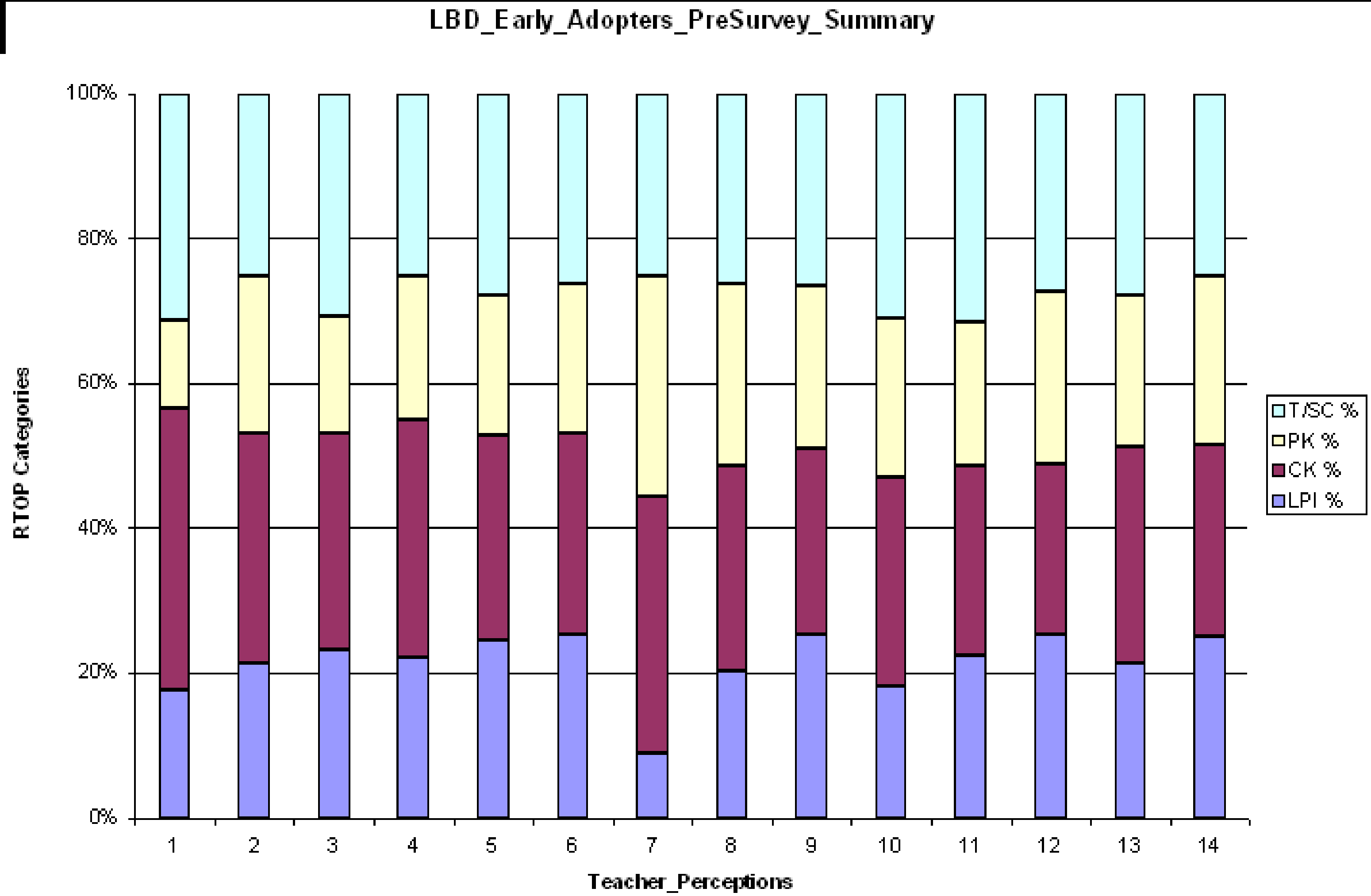
Stop

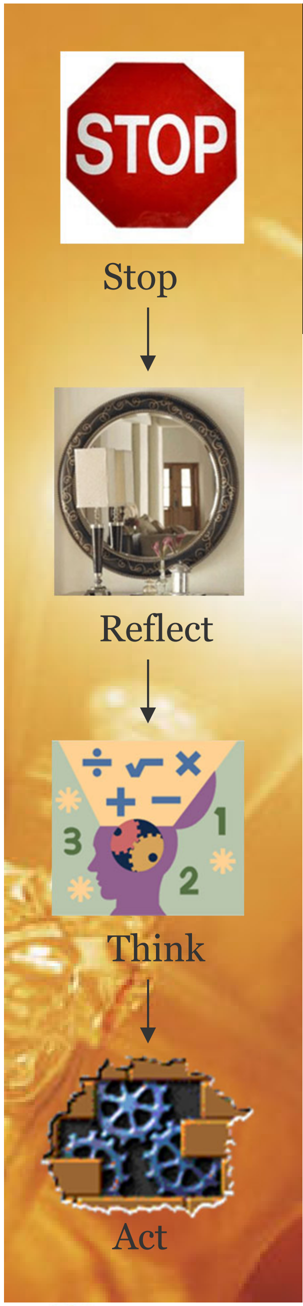
Reflect

Think

Act

Teacher Self-Evaluation

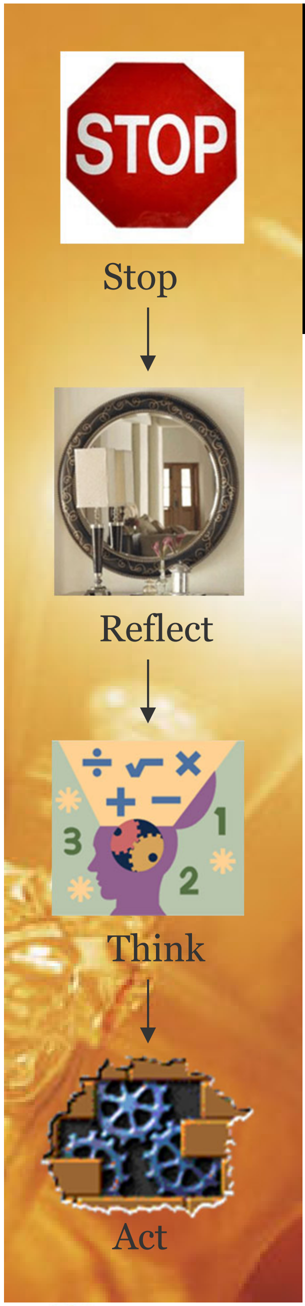




Preliminary Results of Faculty Training

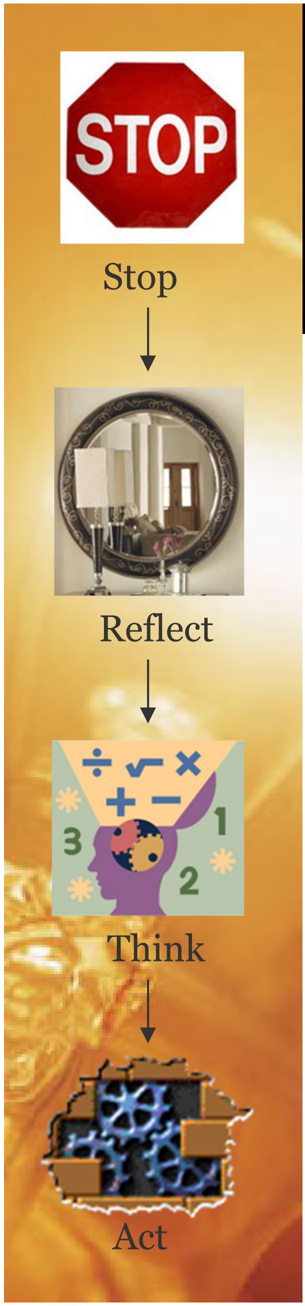
Paired Sample t-test Results of **DL Model Training** – Early Adopters

N	13
Pretest Mean (%)	47.0 ± 3.4
Pretest SD (%)	12.1
Post-test Mean (%)	73.1 ± 1.9
Post-test SD (%)	6.8
t-value	10.711
p-value	<.001
Normalized gain	.4925



Designing Learning FAQs

http://www.doers.us/LBD_FAQs.html



Designing Learning Exemplar

http://www.doers.us/sample_unit_planner.html

Stop

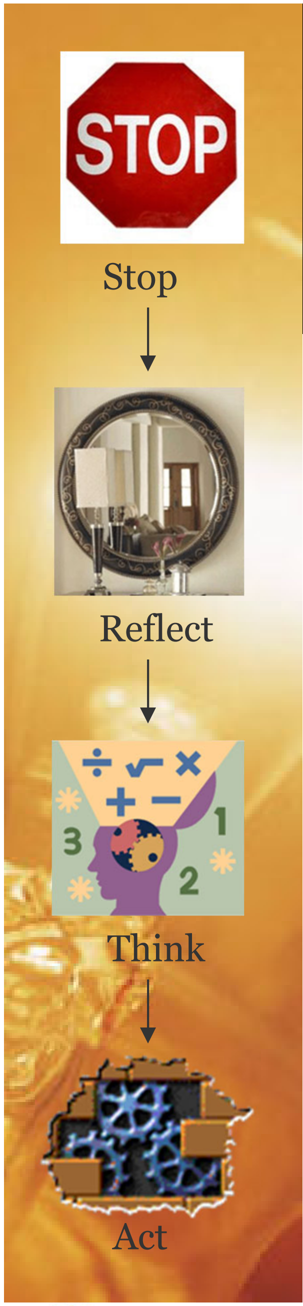
Reflect

Think

Act

Unit Planner - 1st Draft Scores

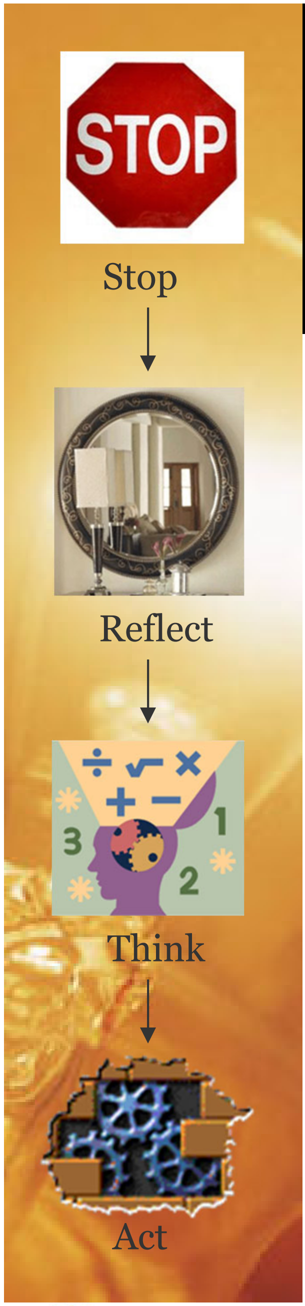
Cohort Mean = 82.6%		Kuder-Richardson (KR20) $\alpha = 0.9752$	
Grader	**N**	**Mean (%)**	**SD (%)**
1	13	86.3	8.3
2	13	81.8	9.6
3	13	81.2	8.5
4	13	80.9	8.6



Next Steps

1. Continue using/refining DL Model in my Physics Classes
2. Check out how it works in my Physics Engineering Technology Class
3. Compare & Report on the pre-post results of my students in FMCI & CSEM next year
4. Observe what the Designing Learning Model does to the freshmen students in the treatment group at my HS
5. Use the Designing Learning Model to develop challenging "SET" curriculum

6. More importantly, I would be delighted to **collaborate** with anyone interested in building on this work



Short Video Clip

Stop

↓

Reflect

↓

Think

↓

Act

So Prince Rescued Princess ≡ ?

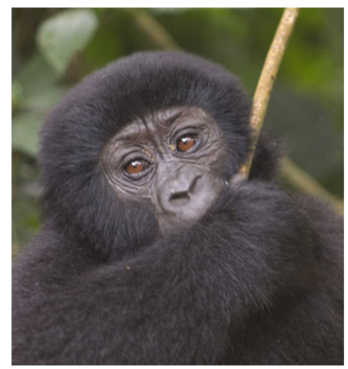
? ≡ I submit that . . .

by intentionally and explicitly focusing on Higher-level Literacy Skills through challenging, engaging & motivating activities/problems/contexts (like the the Learning *by Design* (**LBD**) Model)

Every student will value, know and be able to do physics and see its

- Real-world connection !!
- Relevance $

•**Central Role** in furthering Science, Engineering & Technology Education ↺



Questions?

? ?

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