Visual Physics at TAMU: A Snapshot of our Reform Methods and Their Application to Recitation and Lab

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How It All Began

Fall 2002: Peter McIntyre’s Vision, Visit by Ken Heller

Spring 2003: Pilot project in recitation & lab with NO technical writing and NO TA Instruction

Fall 2003: Full study of CGPS recitation with TA Instruction AND Technical Writing. Lab redesigned using LabView.

Impact on:

- **Exams** (conceptual multiple choice similar to FCI items)
- **Homework** (TW lab reports, online interactive simulations)
- **Lecture** (periodic concept-rich lecture quizzes)

Spring 2004: Mentor TAs, CPR, CGPS scenarios revised….

Fall 2004: New Mentor TA Guide, revised labs, research continues….

Spring 2005: Redesigned course for Fall 2005 and beyond….

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PER Research has Demonstrated a Need for:

- **Professor/TA/Student to Communicate as a Team, Interactively**: (Heller & Heller, 1991; Edith Yerushalmi, Ken Heller, Pat Heller, Charles Henderson, & Vince Kuo August, 2000, and many more examples).

- **Break down Concepts for Transfer so that Tightly-bound “Content-Aggregates” can produce conceptual Change** (Larkin, 1989; Driver, 2000).


TAMU Rationale for Reform

- Lack of retention of physics concepts/skills in subsequent classes
- Unacceptable attrition rate/low course grades
- Dearth of physics majors arising from course (Physics 218 is the first course for all majors)
- Dissatisfaction with lack of articulation of course components by professors, graduate teaching assistants and students
- Demonstrated need for curriculum reform
Visual Physics: Beginning Goals

- Presenting Visual Physics (VP) as a systematic reform of the lab and recitation sessions in PHYS-218, the calculus-based freshman physics course.

- Implementing visual physics (VP) 218 program at TAMU as a fresh approach to recitations and laboratory experiments accompanied by technical writing (TW) instruction in PHYS-218.

  (This approach was inspired by the work of Pat and Ken Heller at the University of Minnesota and decades of research in how students learn first-year physics).

- To begin to create a learning experience in lab, recitation and technical writing sessions that builds students’ understanding and confidence in using the tools of physics and in communicating what they have learned.
Some Over-Arching Questions We Asked

- Are there differences in students’ understanding of basic concepts in Newtonian mechanics before taking VP 218 compared to their understanding at the end of the course?
- Was the interactive-engagement model effective in recitation and lab? If so, in what way?
- What is the impact of TW instruction on writing the scientific lab report?
- Can a partial reform of physics 218 be successful in improving student conceptual and mathematical understanding of fundamental physics principles?
- How can the VP model be improved to have a greater positive impact on student learning?
• “Perspectival” Nature of Model-based Reasoning (Giere, 1997)


• Increased Interactions for Recitation and Lab between TA and Students and between Students (Arons, 1991; Van Heuvelen, 1998; Hake, 1998; Beichner, 2004).
Fundamental Physics Principles + Specific Applications

Abstraction: idealization of real world during problem solving

Creating a “Family of Models” of the Real World

Conceptual  Assumption-based  Graphical  Mathematical

Generating Hypotheses and Generalizations

Multiple Representations of Concepts

Using models to construct meaning

Concretization: adding complexity back into the model, checking for connections and revising

Real World

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Redesign of Introductory Physics

Five Not-so-Easy Pieces

Lab w/ TW

Recitation

Homework

Exams/Assessments

Lecture

And Adding a Sixth: TA Pedagogical Instruction in Reformed Teaching Methods
LAB: Technology Intensive with Embedded Technical Writing

TA Pedagogical Instruction: Explicitly Modeled Interactive-Engagement Techniques (EMIT)

Recitation: Building Solution Models using CGPS
• Lab experiments -- direct visualization, and numerical modeling in the language of physics
• Lab View with real-time interactivity and cooperative grouping
• Instruction in Technical Writing with Lab reports following a template and are in the genre of either:
  • A short technical paper in IEEE format
  • Or a position paper for an informal science journal
  • Or a formal report that students upload to the web (Calibrated Peer Review)
• Newly Revised Interactive Labs
• Developed an Instructional Reform Model: Explicitly Modeled Interactive-Engagement Techniques (EMIT) based on proven reform methods
  • Framed and Assessed using RTOP
  • Initiated into the lab by emulating the “training model” used in TA instruction
  • Modified in response to TA, student and program needs
  • Online TA Course

• Use of Consensus and Negotiation During TA Instruction and Problem Solving
• Designing Content-rich Problem Scenarios by breaking down Conceptual Aggregates
• Learning Cognitive Coaching Methods by Modeling and Assessing TA Teaching
Cooperative Group Problem Solving

- **TA (Expert):**
  - **Initial** modeling of method desired (scaffolding with fading)
  - Student questions and comments shaped the interactions
  - Student prior conceptions were respected
  - Socratic questioning and other techniques were used to refocus groups as needed
  - Used “just-in-time” opportunities to encourage student thinking

- **Students (Novices):**
  - Used a variety of representations to construct a “solution model”
  - Negotiated, debated and defined the problem
  - Moved to more expert practice

- **Context-rich Concept Problem Quiz (CPQ) later called Recitation Quiz (RQ) SASD Method of Solution**
  - SASD: Be sure to 1) sketch (w/ Free Body Diagrams, if appropriate) 2) write down ALL of your assumptions, and 3) solve and 4) show how you derive the formulas. Box Answers.
Assessments Used

- FCI pre/post instruction (Students)
- Concept-rich Problem Quizzes (CPQs) every week and Interaction Charts (Students)
- Student Survey of Recitation and Lab (Students)
- MPEX2 (TAs)
- RTOP (TAs)
- 2 “Lecture Quizzes” to assess concept-rich problems practiced in recitation otherwise traditional (Students)
- Lab Reports (Students)
- Exams – traditional except contained a short section of conceptual questions similar to the FCI items (Students)
- Online Interactive Conceptual Quizzes (FM2CA) (Students) See following examples
Flash Simulation Quiz # 3
Comparative Oscillations

Tension:          Gravity:          Ball Mass:
+                 Earth             -  Reset
-                 Moon              +

Enter name:       Student number:  Section number:

Explore changing the motions by clicking on the + and - signs. Determine the factor(s) influencing the differences in the motions.

Answer the question below and justify your selection. If your explorations result in out of control oscillations, reload and begin, again.

Assuming that the ball and cord are similar in each situation, what factors(s) could affect the changes in position and oscillations of the hanging mass?

- A. On the earth, adding more mass will cause a slower oscillation.
- B. On the moon, adding more mass will cause a faster oscillation.
- C. On Jupiter, adding more mass makes no difference in oscillation.
- D. None of the above is true

On what basis could you compare the motions? Could you predict them? How? Enter your answers and explanations in the textbox, below.
Another Simulation

Ball Drop

To the left, are three simulations with falling basketballs that bounce on impact.

Interact with these 3 examples by pressing the reset buttons and then the start buttons. Also move your mouse over the letters under each picture for some descriptions of the motions.

Observe the rate of fall and bounce (recoil) patterns. On the earth, at sea level, and in the absence of air friction, the acceleration due to gravity will be the same, no matter how much mass the ball contains. The ratio of weight to mass gives this acceleration, so as the weight changes, the acceleration changes, holding the mass constant.

Read more about the history of falling bodies HERE

The recoil is dependent upon

- the materials from which the ball is made, which effects the ball's incoming and outgoing speeds -- a "coefficient of restitution."
- the temperature of the ball
- the characteristics of the surface from which the ball recoils, etc.

Read more about recoil HERE

Press only once on the "go" button, below.

Write down your number.

You must enter this number into WebCT Vista in order to have access to your Homework Set.

Generate Your 10 Unique Numbers

Go!
Cohen’s $d$ in measuring an effect size of the change between FCI pre- and post-test scores for each of VP group ($N = 77$) and TR group ($N = 108$). An effect size of 0.25 or bigger is considered to be significant.
Recitation: Building Solution Models for “Context-rich” Problems

- Enhancing students’ conceptual grasp and problem-solving strategies
- Utilizing an “expert” (trained TA) circulating to model for and guide the student through solution model building

**Traditional**

A projectile is fired at an upward angle of 45 degrees from the top of a 165m cliff with a speed of 185 m/s. What will be its speed when it strikes the ground below? (Use conservation of energy).

\[ v = \sqrt{v_0^2 + \frac{g}{2} \cdot s} \]

**Example Student Problems**

**CPQ**

You are worried that bad physics is being taught to children in the movies. So, you have joined a committee that reviews the Spiderman 2 movie. Spiderman is on the ground in front of a menacing ski lift in which Mary Jane (MJ, 50 kg), who is about to be pulled up, is riding. The lift is moving horizontally at a constant velocity of 8 m/s. Spiderman, who is twice her mass, jumps off the lift onto a queue and swings towards Spiderman, who is twice her mass. Mary Jane is standing at a height of 5 m above the ground. When she reaches the top, she grabs onto the top of the lift and they both continue to swing to avoid the Quicksand area.

- In order to approve this movie, the physics must be correct, so you calculate the maximum height Spiderman and Mary Jane can swing to as a fraction of their initial height.
- Calculate MF’s velocity at the bottom of her swing, \( v = \frac{8}{2} \) m/s.
- Calculate their velocity (not after she grabs Spiderman), \( v = \frac{8}{2} \) m/s.
- Calculate the maximum force on her arms, as she grabs Spiderman.
- Be sure to write down ALL of your assumptions, Free Body Diagrams, basic formulas, and key terms. Box Answers.

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PHYS-218 (Fall 2003)
Pre/Post Visual-Physics Lab Reports
(graded analytically on 100-point scale)

- VP/Non-Honors w/o Tech. Writing (n = 34)
  - Pre: 42.9
  - Post: 47.2
  - Improvement: +4.3

- VP/Non-Honors w/ Tech. Writing (n = 46)
  - Pre: 53.1
  - Post: 68.6
  - Improvement: +15.5

- VP/Honors w/ Tech. Writing (n = 36)
  - Pre: 60.5
  - Post: 75.2
  - Improvement: +14.7
While course grades have been demonstrated in other studies to have mixed reliability, depending on the consistency of the grading scale between instructors, they were included here in order to provide a background against which correlations between treatment and control could be seen.
S1: “We made connections with the help of our group members and TA that resulted in a better understanding of the problem.”

S2: “We were encouraged to compare our problem to other examples in the real world, the lab and the homework.”

S3: “Solving these problems requires that our team sometimes disagrees (my partners were forced to apply a free body diagram) but in the end we understand the concept better.”

S4: “Our TA gave us a different idea for the problem than the one we were using, only after we thought about the problem and tried solving it by ourselves.”
Extending VP Studies from Fall 2003 and Spring 2004 to Fall 2004

MPEX2: Probes GTA Physics Expectations:

- **Coherence** (discrete/connected continuum)
- **Independence** (Authority/Student-centered continuum)
- **Conceptual Understanding** (global fit/fact-based)

RTOP: Assesses the *Character* of Instructional Methods

GTA Comments show *Impact* of Instruction on GTA Beliefs

- Training and experience influence GTAs’ beliefs about the *Nature of Physics and physics learning*.
- Since, learning to teach effectively is a process not an event, *skills improve with practice* over time.
- Are GTAs given ample opportunity for epistemological growth?
### TA Results

#### Mean RTOP Evaluation Scores

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<th>3</th>
<th>4</th>
<th>5</th>
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<td>43.00</td>
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#### Type of Interaction

- traditional university lecture (passive)
- university lecture with demonstrations (some student participation)
- traditional high school physics lecture (with student questions)
- partial HS reform (some group work; most discourse still with teacher)
- medium sized (n > 50) university lectures with Mazur-like group-work (ConcepTests) and a student Personal Response System
- modeling curriculum (varies with amount and quality of discourse)

#### Scale

- < 20
- < 30
- < 45
- < 55
- 55-75
- 75-99
Comments on the MPEX2 reflected a widely different attitude about the purposes of instruction and its design. The pre and posttest comments, made by TAs, show that the treatment TAs are concerned with applying the method, during problem-solving, as illustrated in the following comment:

Pretest: TA “B”: “Must understand to really solve a problem correctly.”
Posttest: TA “B”: “Lecture doesn’t always give a deep understanding or knowledge how to apply concept.”

While the control TAs were most concerned about “needing the right formula” and “correct is best:”

Pretest: TA “C”: “Thinking will give the students more understanding, after the lecture.”
Posttest: TA “C”: “Most students rely on lecture only to get the information and don’t practice problems or think.”
● Ask the Right Questions and Listen to Students (Arons, 1986; Hake; 1998; Cummings, et al., 2004).


● Transfer of learning can occur explicitly, implicitly and accidentally. The challenge is to be able to assess the process and positive aspects when it occurs.
A more systematic reform, encompassing all aspects of the introductory physics course – lecture, lab, homework, tests and recitation is needed in order to produce a greater impact on TA’s performance and ultimately on their students’ conceptual gains (Heller, personal communication, 2003).

A greater change between pre- and post-test scores on FCI would be expected if the exams included more context-rich questions in their design. It follows that, if students are to be given skills that are not tested, and, conversely, if they are tested on skills that they have not acquired, success on that test will be limited.
Enhanced opportunities to reveal student (and instructor) conceptions/naïve conceptions during model-building and problem solving for pre-service and in-service teachers are possible with these methods.
- Grant Support for Fall 2005
- Integrates interactive-engagement methods into all elements of the course
- Changes the physical setting for Lecture and Recitation
- Extends Pedagogical Training to the Professors who will work in teams with TAs in a Scale-up like Model
- And, the research continues….