Martial Arts can give you the H.O.T.S.*

* Higher Order Thinking Skills

««« **By Dave Doucette**

Dave Doucette is an old friend of STAO, having developed numerous workshops and articles on Bridging Research into Practic – turning education research into classroom action. In this session Dave married his two passions, martial arts and physics, connecting science concepts to a familiar pastime.

Curriculum Connection: Physics, Elementary through Secondary.

"Everybody was kung-fu fighting..." A zany way to introduce the serious study of the physics of martial arts! But then, this was mid-November at STAO 2006, and at that point we all could use a little comic relief.

Session 2502 began with four martial artists in a dazzling ten minute demonstration, full of sound and fury, chronicling the history of martial arts from mid century Buddhist temples to the blood-spattered mats of the Octagon. I was the lead presenter. I am a lifetime martial artist who happens to have a tiny passion for science education. Ok, not so tiny! The opportunity to combine, for the first time, my two consuming passions, produced an interactive workshop which had participants breaking boards, punching pads, tripping opponents... everything but the 'rear naked choke' (that might not be dignified!)! And, no - you *don't* have to be naked. What were you thinking?

Following this novel start, participants cycled through four stations, each focusing on specific physics concepts in elementary and secondary science . The stations were:

<u>Station 1</u>: **Getting Grounded** (elementary science – stable structures, levers and simple machines)
No one stood on ceremony but all tried standing in basic martial arts stances to demonstrate how stances support a stable structure. They also applied arm-bars and a reaping throw as examples of levers in action.

Photo 1 Matt Owens [left] explains the lever action of an arm bar to a willing participant. Matt, a York University student, is both a former physics student of Dave Doucette and one of Dave's martial arts students.

Nina Dolgovykh

<u>Station 2:</u> You Deserve a Break Today (physics)
Ever wanted to break a board? Hai-yah! Participants did. Well, not a real wooden board but a plastic training board designed for repeated use. They used a speed detector [Pasco Speed Check'R[1]] to determine the minimum speed of hand strikes necessary to break the board. This information was used to examine the mathematical relationship between impulse and momentum change.

Station 3: **Padding the Curriculum** (physics)
'Go ahead, pad, make my day!' Clint might mutter before punching a training pad. Fortunately none of the participants did, but they managed to strike with abandon. Not quite so gleeful in striking the hard surface of a textbook! (We avoided current textbooks, fearing pent-up emotional releases.) They kinesthetically compared varying forces based on different cushioned surfaces, followed by an analysis of impulsive forces.

Station 4: **May the Force be With You** (physics)
'Gimme your best shot'. And they did, onto a protective pad attached to a Vernier Force Plate[2]. This force plate graphically displays on a laptop, the force and time data of the strike. The area under the force-time graph is integrated by the Logger Pro[3] program. The area is a measure of the impulse for a non-constant force. Participants compared striking with the fist, palm, elbow, and knee to examine how maximum forces and times varied with each strike.

How do Martial Arts give you the H.O.T.S. ?

Sounds like fun, you say, but how are *higher order thinking skills* [HOTS] integrated into these engaging activities? Each station is accompanied by a two page guided-inquiry worksheet. It requires students, through a sequence of scaffolded questions, to reflect on the experience and apply specific concepts to the novel contexts.

The stations are examples of "Bridging Research into Practice," utilizing recommendations for 'effective laboratory practices' suggested in *America's Lab Report: Investigations in High School Science, 2006*[4]. The chair of this investigatory panel is Dr. Carl Weiman, 2001 physics Nobel Prize winner, and articulate proponent of science education reform. The report identifies reasons for past failures in attaining broader science literacy and reveals general principles behind recent steps forward.

The following is a flowchart summarizing the successful principles:

1. Sequenced into the Flow of Instruction
laboratory activities are explicitly linked to prior and subsequent learning experiences

2. Clearly Communicated Purposes
transparent learning goals for laboratory experiences maximize student engagement and learning

PRINCIPLES FOR DESIGN OF HIGHLY EFFECTIVE LABORATORY EXPERIENCES

3. Integral Learning of Science Concepts and Processes
content and process are seamlessly woven in learning activities

4. Ongoing Discussion and Reflection
students need opportunity to discuss and reflect, make sense of data, refine and clarify mental models.

Principle 1: Sequenced into the Flow of Instruction

Activities do not have to be 'formal' lab investigations with a purpose, procedure etc. Nor need they verify a principle already taught. There is arguably room for these types of investigations, but they need to be well-supplemented by activities which allow incubation of new concepts, integration of multiple modes of thought (graphical analysis, algebraic reasoning, ratio reasoning, conceptual reasoning, diagrammatical representations) and time for substantive student dialogue. I recall explaining this to a colleague who in frustration said, "But I spoke to them for over an hour about all of this! They just can't get it." That was the problem. In the words of Barry Bennett, education guru and author of *Beyond Monet*[5], "the person doing the talking is the one doing the most learning."

Principle 2: Clearly Communicated Purposes

Students are more likely to be engaged and on task if they clearly understand the purpose of the activities. 'Cookbook style' labs rarely achieve either goal. Students conducting their own investigations are more engaged cognitively but may draw erroneous conclusions and fail to address underlying misconceptions. A guided inquiry worksheet (see below) sequences observations, inferences and conclusions, prompting students to articulate connections between empirical results, kinesthetic experience and formal concepts. Development of effective worksheets is a stimulating, on-going challenge.

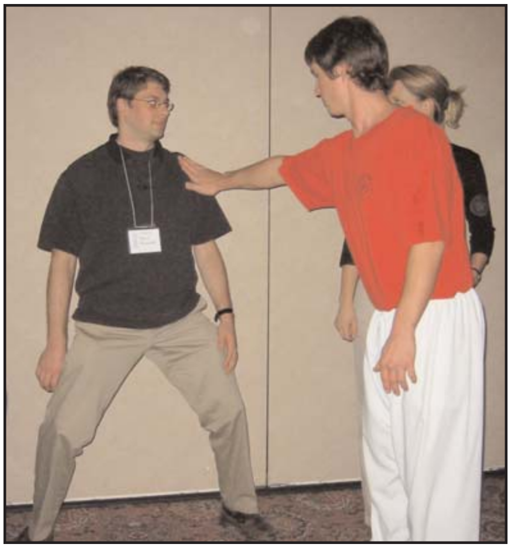
Nina Dolgovykh

Photo 2 Matt Owens, martial arts demonstrator, pushes Mark Reynolds, York U teacher candidate, while Mark maintains a stable structure, keeping his center of gravity over his base of support.

Principle 3: Integrated Learning of Science Concepts and Processes

Unlike traditional labs, which occur after a block of teaching and serve to verify concepts thoroughly presented, these activities often occur *prior* to the introduction of a concept. This permits students to gain experience and begin formulating explanations of phenomenon. When the teacher leads them to the formal definitions and explanations, they filter it through their own mental constructs. This leads to rich, often challenging, and occasionally bizarre student questions. Grist for the mill! Seldom do these classes end with a cursory, "Are there any questions?" to a sea of blank faces… and a teacher smugly thinking, "That must have went well, no one had any questions."

Activities may also occur *simultaneously* with introduction of concepts. In either case the material content and support activities need to be seamlessly integrated. Lab activities occur frequently and may be ad hoc or informal, permitting a short interval for students to interact with materials, engage in peer discussion, and close with a brief class summation.

Principle 4: Ongoing Discussion and Reflection

Peer discussion, mentioned above, is critical to the plan. Students are encouraged to thoroughly discuss the activity, challenge interpretations and articulate points of view. They then transfer their understanding onto worksheets. There is surprisingly little copying as activities are designed to be comprehensible and students seldom find it difficult to use their own phrasing. When assessing these sheets, teachers easily recognize if the class (or individual) has made correct connections or if serious misconceptions persist.

Much of the success of this principle hinges on the creation of an effective inquiry worksheet. The following are examples of guiding questions [beta version] from Station 4, in which students strike a force plate: (note the graphics have been removed, as have the spaces for written responses).

STATION 4 MAY THE FORCE BE WITH YOU

Part 1 *Strike One*

1. a) Sketch your graph results below, indicating the peak force value and the time interval [F vs t graph]
   b) How much *total impulse* did you exert on the pad?
   = _________ [from the computer analysis]
   c) Describe how your force value changed over time.
2. Indicate the body part you used to strike the pad. Describe any sensations of force you experienced.
3. Assume the person holding the pad is on a frictionless surface and has a total mass of 70 kg. Calculate the change in momentum you would cause to occur to the person as a result of your impulse.
4. What is the total impulse the pad must have applied to your fist, hand, etc.? Explain your reasoning.
5. Was there any evidence of this impulse applied to your fist, hand, etc.? How should the change in momentum of your fist, hand etc compare to the change in momentum of the pad & person? Explain your reasoning.

Part 2 *Strike Two*

6. Strike the pad with a different part of your body.
   Before doing this, predict:
      i) if the *peak force* is likely to be higher or lower. Why?
      ii) if the *time interval* is likely to be higher or lower. Why
      iii) if the *total impulse* is likely to be higher or lower. Why?
   Now try it out and record your results by sketching the graph shape below. Indicate the peak force and the time interval. [graph 2]
7. In addition to an *impulse-momentum* analysis, a *work-energy* analysis could be made for a strike. This is governed by the equation $F \cdot \Delta d = \Delta E$. Discuss how a measurement of the work done by striking $F \cdot \Delta d$ would be different from measuring impulse. Speculate on the most likely energy changes to occur as a result of the work done on your opponent.

Maybe You Should Have Mentioned That, Dave!

Participants in my workshops typically play the role of students; using the same materials, completing inquiry worksheets, conducting peer dialogues and presenting with whiteboards. This mirrors sage advice of a senior researcher in the field of physics education, Dr. Lillian C. McDermott: *"Teachers should be given the opportunity to learn the content that they will be expected to teach in the manner that they will be expected to teach."*

So this was what happened in this workshop. Unfortunately the worksheet questions proved daunting for many of the participants, even a few senior physics teachers. Not surprising. When first exposed to this type of scaffolded questioning a decade ago, I could complete only a few questions with confidence. Standard physics instruction seldom offered opportunity to apply concepts repeatedly in richer contexts to establish deep understanding. My surface level physics was inadequate to the task of detailed synthesis. The good news is... if I can learn it, anyone can. I'm really just a cognitive psychologist. Honestly – they *made* me teach physics...now I'm a 'born-again' physicist. Isn't that justice?

I failed to explain to participants the ancillary nature of the worksheets. The questions were mere background. The focus was intended to be on the sequencing of questions, the levels of thinking required, and the integration of complementary modes of intelligence. The one-hour time slot was so crammed with activity that I neglected to include a focusing introduction and some participants were put off by the level of difficulty. Ouch – rookie mistake.

I should have clarified this. I certainly will next time. This detracted from noticing my senior physics students explaining questions and answers to participants. The student volunteers were included to provide assurance this level of student thinking was achievable.

It is often said one must be willing to make mistakes in order to advance in this craft. You just have to ensure that you learn from the mistakes! Repeating mistakes is the hallmark of mediocrity. I'll be better next year. Next year (STAO 2007) it will not be a workshop for physics teachers only — the conceptual model is applicable to any discipline. Physics is merely the vehicle for transporting the concept. *"Don't concentrate on the finger, or you miss all that heavenly glory"*, stated Bruce Lee in *Enter the Dragon*. He wasn't even a physicist!

I have already restructured the workshop for STAO 2007. For the upcoming conference I will also feature modeling of student reflection, whiteboarding and a rousing closure — a few other incidentals I neglected to include. But the ten-minute demonstration will stay. It was just so much fun. And by mid-November we are all in need of a little light distraction. *"Everybody was kung-fu fighting..."* Yagottalovescience.

Editor's Note: The equipment mentioned in this article is not outrageously expensive; the software is $159.00 and $10.00 for a student five pack, the force plate is $200.00.

References

1. Pasco Speed Check'R. Merlan Scientific Ltd, 247 Armstrong Ave., Georgetown, ON L7G 4X6
   Tel: 905-877-0171 Fax: 905-877-0929. Or goto website: **http://www.merlan.ca/product.aspx?sku=SE-7576&subcat=3&cat=1** to check specifications and pricing.

2. Vernier Force Plate. Vernier Software & Technology, 13979 SW Millikan Way, Beaverton, OR 97005-2886. On the web goto **http://www.vernier.com/probes/fp-bta.html** to view the plate specifications and pricing.

3. Logger Pro. Computer software for the Vernier LabPro interface . Vernier Software & Technology, 13979 SW Millikan Way, Beaverton, OR 97005-2886. On the web goto **http://www.vernier.com/soft/lp.html** to view software specifications and pricing.

4. *America's Lab Report: Investigations in High School Science, 2006*, The National Academies, Office of News and Public Information,500 Fifth St. N.W. Washington, DC 20001. ISBN: 0309096715. To purchase on-line goto **http://newton.nap.edu/catalog/11311.html**

5. *Beyond Monet: The Artful Science of Instructional Integration*. Bookation Inc., P.O. Box 14509, Bayly Post Office, 75 Bayly St.West, Ajax, ON, Canada, L1S 7L4. Fax- 905- 619-0152 Phone 905-619-0376 **eclectic@on.aibn.com** .

6. Lillian C. McDermott, Department of Physics, University of Washington, Seattle, Washington, U.S..A. *Connecting Research in Physics Education with Teacher Education*. An I.C.P.E. Book © International Commission on Physics Education 1997,1998.