Facilitating Students' Problem Solving Across Representations in Introductory Physics

Dong-Hai Nguyen
N. Sanjay Rebello, Elizabeth Gire

Department of Physics
Kansas State University

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Motivation

Multiple Representations (MRs) useful in solving physics problems

- Several studies addressing the benefits of using MRs in solving physics problems.
- Not many studies on how students transfer their problem solving skills in physics across MRs.

2

Some Studies on MRs in Physics

- McDermott et al (1987)
  - Students difficulties with connecting graphs to physical concepts and the real world.
- Van Heuvelen and Zou (2001)
  - Qualitative representations (sketches, diagrams, bar charts) help learning of energy concepts.
- DeLeone & Gire (2005)
  - Non-equational representations were necessary but not sufficient for problem-solving success.
- Meltzer (2005)
  - Students' perform differently on isomorphic physics problems in different representations

3

Research Questions

RQ1: What kinds of difficulties do students encounter when solving problems in multiple representations?

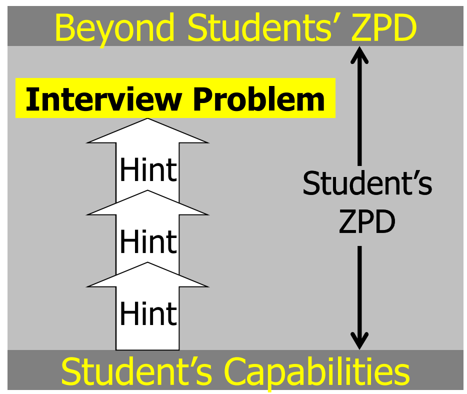
RQ2: What kinds of scaffolding are useful in helping students overcome those difficulties?

4

Theoretical Perspective: ZPD

Zone of Proximal Development
(Vygotsky, 1978)

- Problem presented within students' ZPD
- Hints provided to scaffold process of problem solving within ZPD.



5

Research Context

- N=20 participants
- Engineering majors
- Enrolled in 1st semester calc-based physics
- Topics: Kinematics, Work-Energy

6

Research Methodology

Teaching/Learning Interviews (Steffe et al , 2003)

- Four sessions: One after each class exam
- Each session: 60 minutes, video/audio taped
- Three problems per session
  - 1st Problem: Original Exam Problem (Verbal Representation)
  - 2nd Problem: Graphical OR Equational
  - 3rd Problem: Equational OR Graphical
- Hints provided when students expressed difficulties

Phenomenographic Analysis (Marton, 1986)

- Categorized students' difficulties
- Categorized hints provided by interviewer

7

Example: Original Problem (Verbal)

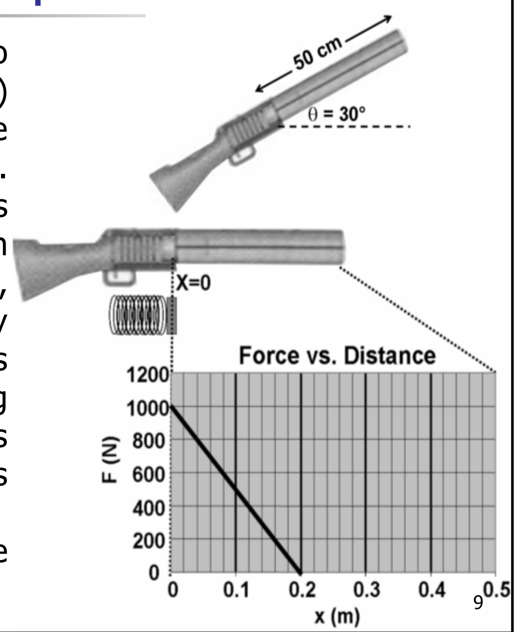
A spring of stiffness constant 3.0 kN/m is compressed a distance of 1.5 cm and a small ball is placed in front of it. The spring is then released and the small ball, mass 0.1 kg, is fired along the slope and launched into the air at point A which is 10 cm above the spring. The angle θ of the velocity at launch is 30°. Friction is negligible.

What is the speed of the ball at launch point A?

8

Example: Graphical Problem

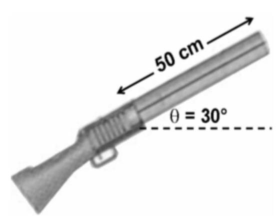
A 0.1 kg bullet is loaded into a gun (muzzle length 50 cm) compressing a spring. The gun is fired at a 30° angle. The barrel of the gun is frictionless and when the gun is horizontal the net force, F(N) exerted on a bullet by the spring as the bullet leaves the fully compressed spring varies as a function of its position x(m) in the barrel as per the graph shown.
What is the speed of the bullet as it leaves the gun?



9

Example: Equational Problem

A 0.1 kg bullet is loaded into a gun (muzzle length 50 cm) compressing a spring. The gun is fired at a 30° angle. The barrel of the gun is frictionless and when the gun is horizontal the net force, F(N) exerted on a bullet by the spring as the bullet leaves the fully compressed spring varies as a function of its position x(m) in the barrel as per the equation shown.
What is the speed of the bullet as it leaves the gun?



$$F(x) = 1000x + 3000x^2$$

10

Results: Difficulties

- GRAPH: processing information from graph provided
- FUNCTION: inappropriate interpretation of function
- PRINCIPLE: inappropriate use of physical principles.
- QUANTITY: incorrect use of physical quantities.
- FORMULA: incorrect interpretation of formulae.
- VALUE: Using incorrect value of physical quantities.
- MATH: Inability to manipulate math processes.
- CALCULATION: simple calculation errors.

11

Results: Hints

- Explicit: Statements
  - Cuing students to refer to some information, prior knowledge
  - Enabling students to recall or apply physics or math knowledge
- Implicit: Questions
  - Asking students to reflect on what physics knowledge and math processes are applicable
  - Facilitating students integrate math knowledge and processes to apply that knowledge to physics problems

12

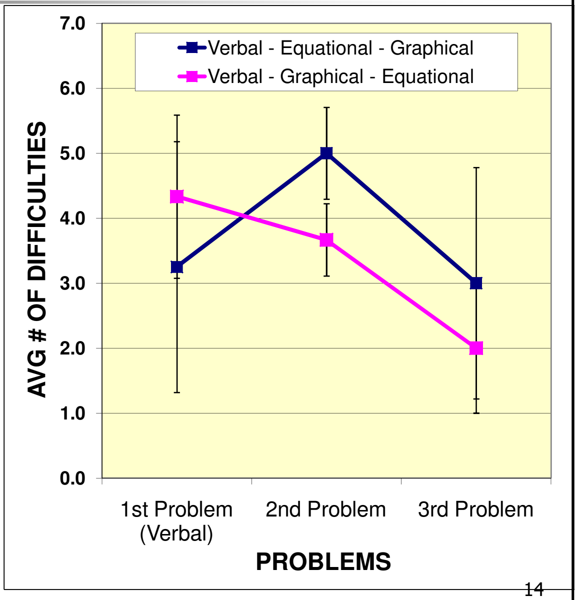
Results: Common Themes

- Case Reuse
  - Tried to mimic the previous problems
    - Example: Finding potential energy for a spring by trying to find the spring constant.
- Graphical Interpretation
  - Instinctively tried to calculate the slope of graph
  - Several hints to recognize integral is area under graph
- Physical Interpretation of Math Procedures
  - Adequate knowledge of math procedures
  - Inability to apply these procedures in physics problems
  - Hints on reflecting on units of physical quantities effective

13

Results: Sequencing Effect

- After verbal problem, fewer difficulties on graphical compared to equation problem (α= 0.1 significance).
- Solving the graphical problem before the equation problem decreased the difficulties in solving the equation problem (α= 0.1 significance), but converse not true.



14

Conclusions

- Students were unable to interpret physical meaning of mathematical operators and processes.
  - Thus had difficulties solving problems in graphical and functional representations.
- When the context of the problem changed, could not relate the new problem to the original problem.
  - Thus had difficulties identifying the principle and physical quantities needed to solve the new problem
- The sequence of problems affects performance:
  - Verbal -> Graphical -> Equation sequence has fewer difficulties

15

Thank You

For further information

Dong-Hai Nguyen
Dong-hai@phys.ksu.edu

Elizabeth Gire
egire@phys.ksu.edu

N. Sanjay Rebello
srebello@phys.ksu.edu

16